American Denture Society Meeting, Adolphus Hotel, Dallas, Texas, Nov. 7 and 8, 1958

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THE JOURNAL OF PROSTHETIC DENTISTRY

VOLUME 8 SEPTEMBER-OCTOBER, 1958 NUMBER 5

COMPLETE DENTURES
REMOVABLE PARTIAL DENTURES
FIXED PARTIAL DENTURES
OPERATIVE DENTISTRY

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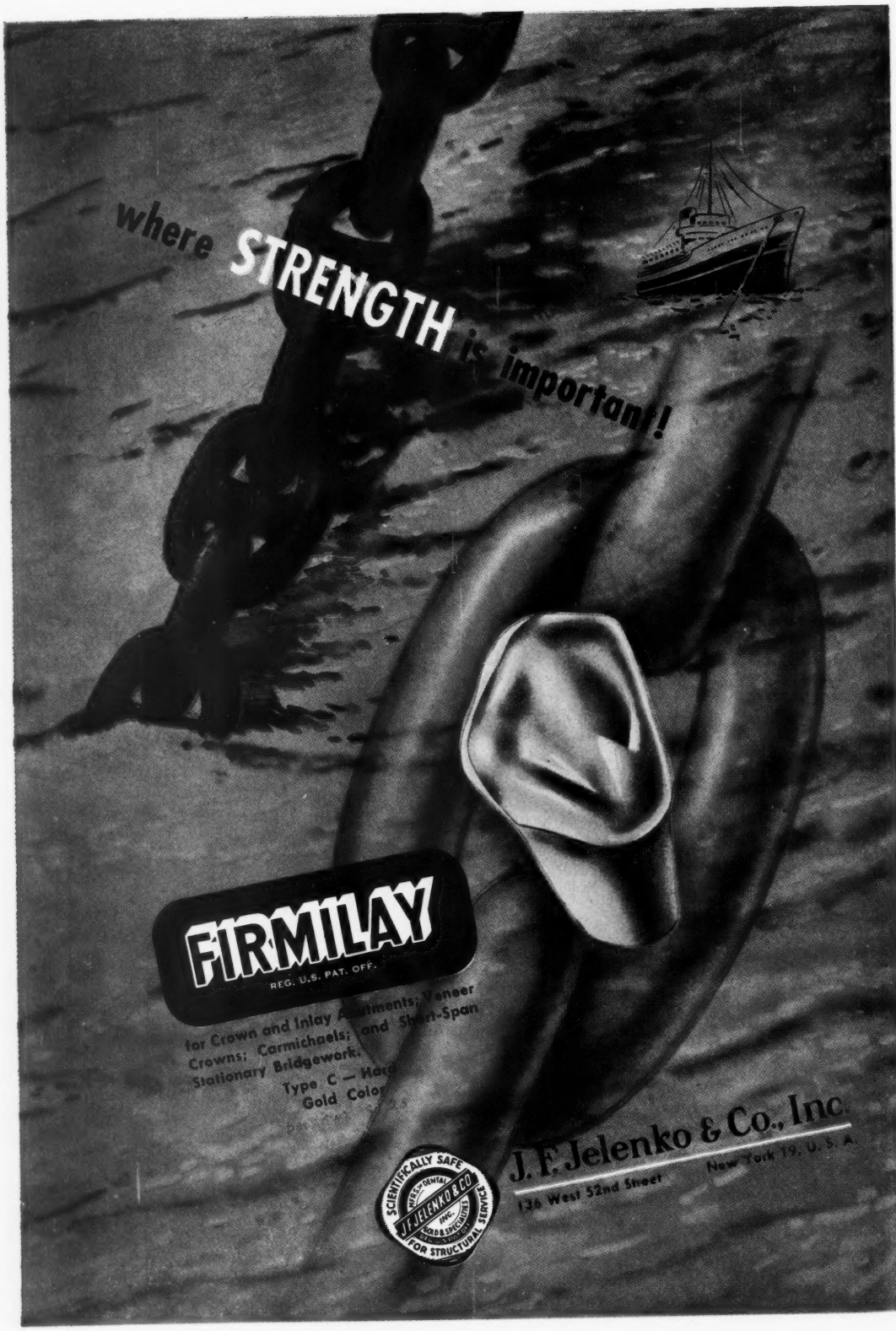
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THE JOURNAL OF
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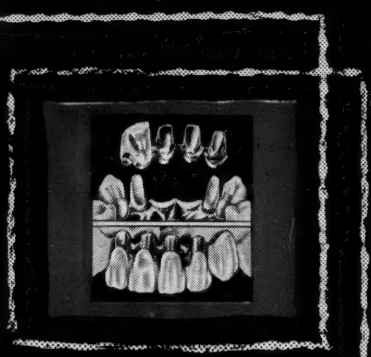

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THROUGH THE EYES OF THE EDITOR

Sol Silverman, Jr. discusses the tissue changes that occur with aging and the way they affect the ability of older people to wear dentures. This is a matter of increasing concern to the dental profession because of the greater longevity of people and the larger number of people who are affected. He cites many general physioanatomic changes in the body which affect resistance and tolerance of these people. He also discusses the specific changes in the oral cavity which are directly involved in the ability to wear dentures. He suggests certain courses of treatment which should be of assistance in caring for the denture needs of older patients.

Wilfrid H. Terrell reviews some of the important fundamentals of complete denture construction and expresses his views on certain controversial concepts which are involved. He suggests that group study can lead to a clearer understanding of the problems which arise because of differences in concepts. Wherever possible, he refers to the information available from the basic sciences since this source is largely free from prejudice. It is in interpretation that differences become apparent. His discussion touches upon all of the major factors involved in complete denture construction. No doubt, there will be those who will disagree with certain of his concepts and techniques, but not all of those who disagree with them will be selecting the same areas for their disagreement. This leads to the thoughts that there is no single way to build successful dentures and that sincere, careful, and intelligent execution of any technique is essential to the rendering of successful denture service. The confusion and misunderstanding that he mentions point up the fact that there may be a need for a new means for evaluating the relative success of denture service. Dentists are at a disadvantage at this point because it is easy to compare their successes with the failures of others, and it is difficult to compare their successes with the successes of others and thus determine which are better. This article should prove to be stimulating to those who are interested in better denture service.

Leslie R. Allen discusses phonetics as it is related to denture construction. The restoration of phonetics is often listed as one of the values of dentures to patients, but frequently this phase of denture service is slighted until a patient complains of his inability to make certain sounds the way he would like to make them. The reason the failure to give adequate consideration to phonetics is not recognized in most instances is due to the adaptability of the patients. By self-training, *most* patients can *learn* to make satisfactory speech sounds in spite of the dentures rather than because of them. Other patients find this more difficult or impossible. The fact that a relatively small group of patients find speech to be difficult with dentures does not minimize

its importance. The suggestions contained in this article should be helpful toward the solution of this problem for patients who find relearning and adaptation difficult. If they are applied routinely, the wearing of dentures can be made less annoying to patients.

Walter A. Hall, Jr. recognizes the importance of occlusion in denture service and describes his procedures for making the necessary jaw relation records and for checking them for accuracy. He points out the necessity for accurately fitted occlusion rims which are built to establish the vertical dimension of occlusion and esthetics. After his preliminary records and mounting have been completed, he institutes a series of checks which should expose errors if they exist. Since the patient's coordination is involved in most of the interocclusal records made by most techniques, repeated rechecking should be a part of *any* complete denture technique. He points out that this rechecking of the occlusion should be done even after the dentures have been completed. This will avoid maladjustment of the borders of dentures if the real cause of the trouble is an error in occlusion.

S. Richard Nepola discusses the use of balancing ramps for providing cross arch balancing contacts when zero degree cusp teeth are used. He sees greater patient comfort without sacrificing esthetics when balancing ramps are used with this type of teeth. He describes his technique for developing the balancing ramp in silver amalgam after the dentures have been completed. The dentures may be remounted in order to rebalance the occlusion after they have been worn for a time. Thus, balanced occlusion can be maintained.

Ralph W. Flinchbaugh describes a method for modifying a Hanau Model H articulator and face-bow so casts can be oriented on the instrument with reference to cranial planes. It involves increasing the length of the posts so the space between the upper and lower members of the instrument is increased. The methods for modifying both the articulator and face-bow are quite simple and practical.

G. A. Lammie, H. T. Perry, Jr., and B. D. Crumm report on their investigations of the effects on function when occlusions were developed at different maxillomandibular relationships. The studies were made of dentures built to occlude at five different positions within the envelope of motion, as described by Posselt, and at one position which was artificially retruded beyond the normal envelope of motion. Three classes of results were obtained for comparison and analysis. These were the comments of the patient, chewing observations, and electromyographic records. This article provides the background for further observations which will be reported in Part II of this series.

David H. Anthony and Paul Gibbons discuss denture cleansers—a problem of great interest to most denture patients. They found that many substances are being used to clean dentures and that there is considerable variation in their effectiveness and in their effect upon the dentures themselves. They point out that surface scratching or abrasion of the denture base and corrosive action on base metals in dentures are caused by some cleansing methods and materials. They did not report on the bactericidal and fungicidal effects of the cleansers, and this should be considered.

H. A. Young discusses the trauma which may result from improperly developed occlusion and describes his techniques for eliminating it from dentitions and dentures. He points out several causes of occlusal trauma and suggests procedures to avoid it. He does not favor the use of stress-breakers but chooses other means to accomplish his objectives. His primary concern is in relation to occlusion, where removable partial dentures supply part of the occlusion.

G. P. Ivancie discusses the interrelationship between restorative dentistry and periodontics and concludes that periodontal health is the basis of successful restorative dentistry. He discusses the prosthetic considerations involved in periodontal health and recommends certain criteria for determining the status of the periodontal tissues. He sets up specifications for the occlusion and rates malocclusion as a secondary cause of periodontal disturbances. There are others who place greater emphasis upon malocclusion as an etiologic factor of periodontal disturbances. The shape of the restorations of the clinical crowns of teeth is shown to affect the periodontal health of the teeth involved. He shows a means for avoiding this trouble.

Arthur S. Freese discusses the causes and treatment of temporomandibular joint disturbances. He notes that some of these are dis-

turbances of the joints, but that more of them are due to disturbances of the mandibular musculature. He reports that the mandibular muscle spasms have three salient symptoms. He discusses each of these as well as four classes of temporomandibular joint disturbances and suggests procedures for a differential diagnosis. An accurate diagnosis is essential to treatment. His recommendation that any treatment instituted be conservative seems to be sound. The suggested treatment for each of the types of disturbances is logical in relation to the diagnosis.

E. Carl Miller discusses the biologic approach to operative dentistry. He points out many factors which, if properly handled, lead to the success of treatment. If these factors are not given adequate consideration, the treated tooth will be lost and the objective of operative dentistry—to save teeth for the entire life of the patient—will not be achieved.

Robert C. McKay reviews the history of the development of instruments used for preparing teeth for restorations. This is a timely subject, since we are prone to forget the valuable work of those who preceded us. The progress from the foot engines, of 1920, to the high-speed handpieces of today is tremendous. The author compares the various cutting instruments, equipment, and techniques which have been developed recently and points out his preferences based upon his experiences with them. No doubt, more time will be required before the ultimate in efficiency and safety is reached.

Irwin D. Mandel discusses various preventive techniques which may be adjuncts to operative dentistry. He recognizes that prevention rather than repair is the ultimate answer to the problem of dental caries. He gives his evaluation of each of the current preventive measures and concludes that even though the complete solution has not been found, progress has been made.

George M. Mumford and Ralph W. Phillips make a preliminary report of their research on the thermal expansion of crystobalite investments in the inlay ring. They found that the expansion of the investment is restricted by the metal ring and suggest a technique to avoid this difficulty.

Joseph S. Landa continues his critical analysis of the Bennett movement. In this part, he repeats the optical method used by Bennett and points out possible fallacies in the method. He then uses the Reuleaux method to analyze Bennett's illustrations. He failed to find the "considerable" shift laterally which Bennett used. It should be noted that, like the investigations reported by Bennett, these observations were made by using only one subject. The significance *might* be that the lateral shift does occur in some individuals and not in others.

William L. Kydd describes the equipment and the use of rapid serial roentgenographic cephalometry for observing mandibular movements. The procedures do not appear to be too complicated to be practical for research purposes, and they may help us to a better understanding of mandibular function.

Honorato Villa A. reports his mathematical studies of mandibular movements and, on the basis of these, he proposes an "elliptical theory" of occlusion. This concept is worthy of further study. While it appears to differ from other concepts, the end result may be the same. Varying lengths of the radii from the cuspal inclines to their theoretical center of movement may account for the differences between the concepts.

John J. Sharry discusses the use of meatus obturators for cleft palate patients. This comparatively new type of appliance works on a different principle from the usual hinged or fixed obturators, and it appears to merit further study. It functions on a different principle from the usual speech appliances and does not require a long training period for the muscles involved in its use. The technique of construction eliminates the necessity for complicated pharyngeal impressions.

Hugo A. Owens reports successful replantation of a tooth for a 13-year-old boy. Certainly, replantation has advantages over an artificial replacement when it is possible. Probably, the age of the patient and the meticulous care used in the treatment were factors leading to the success in this instance. It is remarkable what nature can do, if given the opportunity.

—Carl O. Boucher

COMPLETE DENTURES

GERIATRICS AND TISSUE CHANGES—PROBLEM OF THE AGING DENTURE PATIENT

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THE SUBJECT OF GERIATRICS is increasing in importance because of the great age shift in our living population. At the present time, more than one-third of the American people are above the age of 45. Nearly 13 million, or more than 8 per cent of the population, exceed the age of 65. Statisticians estimate that over 11 per cent will be in this group by 1975. This directly affects the prosthodontist for two reasons: first, because of the larger number of people requiring prosthesis due to loss of teeth through age, and second, the subsequent effects of aging upon tolerance or adaptability to these appliances. In essence, the problem presented is that of a static prosthesis which must be kept in function on a dynamically changing base. Therefore, the purpose of this article is to discuss the geriatric tissue changes that may affect this tissue-denture relationship.

BACKGROUND

In order to form a basis for the material to be covered, the leading texts on geriatrics were reviewed along with current material contained in the *Journal of Geriatrics* and certain other references. This was then sifted for clinical validity by personal communications with prosthodontists of outstanding clinical experience and with physicians who deal with problems in these fields. The results of this survey confirm the fact that there is a problem, but they stop short of the answers which are sought. Many reasons account for this void. There are relatively few men adequately trained or dedicated to the geriatric problem. Also, within this field, the greatest effort seems to be directed toward psychodynamics. Further, most evaluations are in the nature of the effects of growing old, and very little is offered in the way of therapy.

Presented at the 87th Annual Meeting of the California State Dental Association, San Francisco, April 16, 1957.
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*Assistant Professor of Dental Medicine and Chairman of the Section.

GERIATRICS

Geriatrics refers to the study of the aged. However, aging begins early in life, and differences in acceleration of this process will greatly influence the signs and symptoms of "old age." This varies a great deal from individual to individual. For example, there is the 60-year-old person who looks, feels, and acts much younger than a 40-year-old. Aging also varies within each individual; for example, the 60-year-old with good kidney function is much younger in respect to that organ system than the 40-year-old with poor kidney function. These conditions are influenced by such factors as mode of living, accidents, disease, stress, or heredity. Therefore, two more terms may be mentioned at this point: *senescence,* which refers to normal physiologic aging, and *senility,* which may be defined as pathologic aging. Senescence and senility may or may not conform to chronologic aging. Differentiation of these terms is important; for senescent changes are often subclinical and may be the cause for unsuspected problems, while senility is usually obvious to the clinician who can then take proper precautions.

Obviously, describing old age as far as the individual is concerned is often extremely difficult. Therefore, it is sometimes easier to define aging in relation to the properties of individual cells or systems. We are still a long way from understanding the mechanism which winds the life of the organism to a peak and then lets it slowly run down; but it is in the cell itself that we must seek the answer to this most perplexing problem.

Since the question as to "what is aging" brings forth so much controversy, for the purpose of this discussion it will be assumed that aging conforms in general with chronology, and most attention will be focused on the older one-third of our population. These people are the main denture wearers and certainly the group where most concern arises; for from this group come the greatest cellular changes that may adversely affect the acceptance of a prosthesis. Adequate technical accomplishments will be assumed; for naturally, a faulty prosthesis would cause local problems unrelated to senescence or magnify existing problems that will be presented in this text.

ORGAN SYSTEM CHANGES

Physio-anatomic changes, called senescent degenerations, occur in every organ and tissue in the body. The individual variation is due mainly to a time factor (exclusive of disease). The essential change is dehydration and waste of tissue which is either not repaired at all or is replaced by tissue of a different character. These alterations in cellular function and growth may be illustrated by some of the general changes observed in the aging population.

Gastrointestinal System.—There are dilations of the intestine and stomach along with progressive atrophy of the glands. This may contribute to some of the problems of absorption and bowel irregularity which are characteristic of the aged. There is a progressive achlorhydria. These alter the absorption of such essentials as calcium, iron, and vitamin C. There is a reduction in the activity of proteolytic enzymes.

Glandular System.—Combinations of progressive atrophy, fibrosis, sclerosis, and fatty degeneration afflict these organs. Diminished functions with subsequent alterations in metabolism, nutrition, enzymatic, and hormonal relationships contribute significantly to the process of aging.

Examples of these changes are the relationships between the liver and proteins and the B complex vitamins; the thyroid and metabolic rate; the parathyroids and Ca/P ratio; the adrenals and pancreas in carbohydrate metabolism; the kidneys in acid-base balance and disposition of end products; and gonadal tissue and generalized hormonal effects.

Cardiovascular System.—Decrease in blood volume and hemoglobin and loss of cardiac efficiency along with vascular changes tend to deprive tissue of optimal oxygen supplies. Many geriatricians call this fact the underlying basis for senescence. Hypochromic anemia due to factors such as achlorhydria and diarrhea is relatively common.

Respiratory System.—Here again a gradual fibrosis decreases respiratory efficiency leading to problems of oxygen exchange.

Muscular System.—Loss of elasticity and resiliency from dehydration is the underlying basis for a generalized impairment of function.

Skeletal System.—Organic matrix appears to decline, which alters the bone, forming a typically brittle bone structure which may easily fracture and which heals with difficulty. There are also changes in the marrow which becomes gelatinous and contains relatively more fat than younger bone.

Integument.—The skin becomes thin, dry, and inelastic with atrophy of sebaceous and sweat glands; disappearance of subcutaneous fat and hyperkeratotic areas become apparent.

Nervous System.—These cells reach the highest degree of specialization, undergo senescence, and die without being able to divide anew. These cells lose the capacity to reproduce about the end of the first year. It is in such cells that the changes due to age are most evident. Many of the bizarre and nonspecific clinical complaints categorized as functional may well be due to these microscopic organic changes.

ORAL CAVITY CHANGES

The above survey illustrates many of the degenerative changes contributing to physiologic aging. Of importance to the prosthodontist primarily is the effects of these inevitable changes on the oral cavity.

Bone.—This is the most important tissue to the prosthodontist. If bone could be kept in equilibrium, problems of maintaining dentures in function would be greatly diminished. However, in senescence, anabolism decreases while catabolism slightly increases, which lays the groundwork for a dynamically changing base. Production of matrix is further impaired by a diet usually low in protein. Approximately 20 per cent of the body protein is contained in the bone matrix. There may be a decrease in calcium content of the bone, not only due to defective absorption from the gastrointestinal tract but also in the ability of bone to retain calcium,

resulting in greater urinary losses. It should also be recalled that senescent cells absorb more calcium than younger cells. Subclinical vitamin deficiencies as a cause of impaired bone metabolism may be assumed, but they are difficult to demonstrate. Further studies on estrogen deficiencies and resultant osteoporosis in the postmenopausal female will undoubtedly contribute significantly to a better understanding of the metabolism of the aging mandible and maxilla.

Connective Tissue.—The main change in this tissue that forms the cushion between epithelium and bone is an increasing fibrosis. This, along with altered metabolism, causes an increased susceptibility to trauma and a decreased power of repair.

Epithelium.—This tissue retains much of its younger characteristics of growth and repair because of its constant division into new components. However, there is a gradual reduction in growth and repair functions and an increased susceptibility to irritations in the response form of hyperplasias, ulcerations, and keratoses.

The most dangerous problem associated with epithelial changes in the aging patient arises with the increasing incidence of oral cancer which accounts for approximately 4 per cent of all cancers. Since over 90 per cent of all oral cancer is squamous-cell carcinoma, we are referring to malignant degeneration of the epithelium. Well over 75 per cent of these cancers are in the group of persons 50 years and over, indicating that this is a disease of the aging population and a geriatric problem. The cause seems to be an apparent predisposition in a cell to attain an extremely youthful mutation and vigorously multiply in a purposeless manner at the expense of all surrounding life. The high coincidence of these lesions around denture borders always brings forward the speculation of irritation as an etiologic factor.

Nervous Tissue.—Although it is reasonable to suspect systemic influences as playing a primary role in cases termed "denture failures," one must examine the psychologic factors. In a negative sense, this is exemplified by many patients who tolerate obviously poor dentures extremely well. Conversely, many well-made dentures fail because patient acceptance is being retarded by many types of emotional problems that are known to exist. While the problem may seem purely functional and superficial to the dentist, it is real to the patient, and it is often strongly fixed on the prosthesis. These differences cannot often be rationalized; but they must be resolved. This is usually not accomplished by trimmings or remakes, and the differences are often further aggravated by suggestions that "the trouble is in the patient's head." By and large, the most common group in which these difficulties occur are the postmenopausal women with concomitant complaints of altered taste and burning sensations. Local changes in nervous tissue threshold and metabolism, which are poorly understood, may further contribute to vague symptoms without detectable evidence of physical or organic lesions.

Therapeutic Rationale.—It is well established that these changes occur, and it is very evident that the prosthodontist must be concerned about geriatric tissue changes. However, of concern to the prosthodontist are the factors of recognizing senescence and what can be done to control the apparently irreversible degenera-

tions of aging. The prosthodontist must first realize that the signs and symptoms of senescence are generally subclinical except for physical characteristics of chronologic aging. This is in contrast to clinical signs of senility which are the obvious pathologic manifestations of aging. Therefore, the obvious signs such as diarrhea, kidney stones, pallor of anemia, dramatic losses in weight, and characteristic glossitis will not be evident. Thus, the poor denture risks of senility can be rather easily detected and referred for treatment. The more common, symptomless aging person, who is passing unremarkably into dotage, must be handled by general supportive measures.

Careful examination and screening procedures should be carried out. Results of recent medical examinations should be known, or a physical examination requested. Changes in the aging patient can come about rapidly; therefore, current evaluations are desirable. Often simple screening methods, such as a complete blood count and urinalysis, are of value in detecting such disorders as anemias and diabetic tendencies. These tests are simple and inexpensive. It is the dentist's role to realize deviations from normal, and not to make the diagnosis. General questioning as to shortness of breath, urine and bowel habits, dizzy spells, weight loss, etc., may be of value in referring the patient for medical consultation. These may be considered subclinical when the patient accommodates to these changes without seeking professional advice.

FUNCTIONAL VERSUS ORGANIC PROBLEMS

The dentist cannot afford to overlook the mounting number and variety of dental psychiatric problems. These often do not come to light until the denture is delivered. At this time, the dentist must rule out organic or physical reasons before accepting a functional basis. Most experts seem to agree that patience and understanding on the part of the dentist, as difficult as they often may be, are the first steps in treatment. Frequently, by establishment of rapport with the patient and expenditure of time, these problems can be mitigated. Unsuccessful resolution stems from impatience, lack of concern, and insistence on a psychosomatic etiology. Psychiatrists do not meet with much success unless a patient recognizes his needs and is willing to cooperate. Medical consultation, in many instances, only further excites the attention already directed toward the prosthesis. On the other hand, use of sedatives and analgesics, ointments, sialagogues, and local anesthetic injections often aid during these periods of tension and dissatisfaction. Many times these diagnostic measures become therapeutic. Postmenopausal women are the chief members of this group. Unfortunately, the side effects of estrogens, such as bleeding, salt retention, and possible etiologic influence on uterine and breast cancer, contraindicate unlimited systemic support.

NUTRITION

Another supportive measure for evaluation is the nutritional aspect. In spite of the fact that the average diet probably contains at least the minimal nutritional

requirements for the aging individual, so little is known about losses during preparation of foods or the effects of impaired absorption and utilization that we can assume the need for supplementary support. Food fads, for various reasons, further complicate dietary needs. This is supported by the observation that many persons feel much better after extra vitamin and mineral intake, even though a dietary analysis may not reveal the need for this extra supplementation. Since clinical tests for vitamin deficiencies are difficult and overdosage is unlikely with the usual preparations, recommendation for multivitamins on a supportive basis seems proper. The two contraindications seem to be only expense and the possibility of masking symptoms of other chronic underlying disorders. However, vitamins alone are not a substitute for a well-rounded diet. Adequate intake of high quality protein and calories are equally important.

This more understanding approach to the disturbances that characterize the aged and the realization that the oral cavity is an integral part of the entire body will aid in maintaining optimal health for the aging patient and better relationships between him and the prosthodontist.

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FUNDAMENTALS IMPORTANT TO GOOD COMPLETE DENTURE CONSTRUCTION

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THE OBJECT OF THIS essay is to review some of the important fundamentals of complete denture construction. Each of us has a denture technique for which he is indebted to many others who have given him their ideas based upon their experiences and those of others. My immediate objective is the translation and transmission of information and inspiration which may help in the evaluation of the confusion and contradiction which is now prevalent among our prosthetic leaders.

Prior to the 1957 annual meeting of the Academy of Denture Prosthetics, the program committee and eight other members of the Academy prepared a list of comprehensive questions related to the subject of complete denture construction. This was prepared as a questionnaire which was answered by each member of the Academy. It was then discussed in detail at the meeting. There is a wide variance of opinion on some subjects, but an agreement in general on most of the *fundamentals.* The Academy hopes by these studies to arrive at a set of *basic principles* or fundamentals upon which the majority are agreed. The results are being compiled and will probably be published in the JOURNAL OF PROSTHETIC DENTISTRY. This should be very valuable as a guide, particularly for those whose experience with various techniques and methods has been limited. There is no textbook or authority that can give us the correct answer to every question. There are too many ways to arrive at a satisfactory result to say that there is *only* one way that is best.

Practical improvement is more important than theoretical satisfaction but one should be based upon the other. The personal equation is an unknown variable which affects the dentist and the patient in every case. That factor called judgment, based upon experience, will always be an invaluable aid in denture work and a key to success in the handling of prosthetic patients. A technique that is valuable to the average prosthodontist should be one that is not too difficult to execute. Most men do better to add some steps to their present technique for greater accuracy than to attempt to change their whole method of procedure. To learn to use an entirely new technique requires time, study, and practice. A dentist with a busy practice does not have time for this, and, besides, he should not practice on "his good patients." This is where *study clubs* are valuable. Postgraduate courses can be taken by groups, followed by the formation of study clubs making dentures for patients.

There will always be a better way, for that is progress. Perfection has never been reached, and no one has the final answer. We should be both tolerant and

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open minded. Because something is new does not necessarily mean that it is better, but it should bear investigation, and it may be a valuable contribution.

ANATOMIC LANDMARKS OF EDENTULOUS ARCHES

The Maxillae.—

Tuberosity area: The buccal fold in this area usually extends quite high, and many impressions fail to record it completely and accurately. Air is often trapped, or the impression material is not of a consistency to flow to the top of the fold. In making the preliminary impression, it is very important to have a tray which will carry the impression material high in this area. The consistency of the material, whether it be alginate or hydrocolloid, should be fairly stiff. If a small amount of the impression material is placed in the buccal fold with a spatula, and some is placed in the center of the palate before inserting the tray, a good impression should result. Imperfections in this region are frequent causes of upper denture retention failure. We should be rigid in our criticism of our own efforts.

Zygomatic arch: The zygomatic arch is located above the first molar area in the buccal vestibule. This area can be utilized in some patients for denture support and stability, while in others it must be relieved.

Buccal frenum: Examination of the region of the buccal frenum, which is just back of the cuspid eminence, should be made before making the impression and later checked in the impression to see if it has been properly recorded.

Cuspid eminence: The cuspid eminence is the highest point along the border of the upper denture in most cases. Impressions often fall short of this. Sometimes absorption is greatest here, and it is necessary to reproduce this eminence on the labial surface of the upper denture. However, care should be taken not to overdo this.

Labial frenum: The labial frenum may be a single, double, triple cord, or a fan-shaped attachment of connective tissue and mucous membrane. It becomes very sore if it is restricted, and often too much of the denture is trimmed at this point in order to allow for swollen and inflamed tissues. This should be cared for in the impression, and no trouble should be experienced when the denture is worn. Surgical alteration of the frenum is contraindicated in most cases.

Rugae area: The rugae area should be faithfully reproduced on the tissue side of the denture, but not necessarily on the palatal surface. As a rule, patients who have been wearing a smooth denture do not like the reproduction of the rugae on the palate of the denture. On immediate restorations, it can be done, and this often will overcome a tendency for whistling when the S sounds are enunciated. The large central papilla of the rugae (incisive papilla) is easily irritated by pressure, and it is well to give it a little freedom. The anterior palatine foramen is near the papilla and a burning sensation may be experienced due to pressure on it. Many do not like to place an arbitrary relief in the palate of the upper denture because a lack of contact, or the presence of air under the denture, will cause much annoyance. It is usually preferable to have tissue contact under the entire denture at first, and then correct it carefully if pressure areas develop. These can be located very easily with indicator gel or pressure indicating paste.

Torus palatinus: The torus palatinus is the hard, bony area which is sometimes found in the center of the palate. It varies a great deal in size and is not pathologic. It is not a bone tumor as is sometimes suspected. It is not necessary to remove it in order to make a satisfactory upper denture. The denture can be waxed a little thicker over it to allow for relieving it if it becomes necessary, and this bulk can be reduced later when the denture has settled.

Palatal seal areas: The postdam area or the posterior palatal seal area extends between the pterygomaxillary notches and usually passes through the palatal fovea. There are various ways of providing this seal. Some prefer to do it in the mouth in the impression, and others prefer to do it on the cast where they have definite control of the location and the amount of pressure to be applied. It is not necessary to apply the maximum pressure the tissues will allow, for a light seal is all that is necessary if it is properly placed. There are some impression techniques which advocate the elimination of the postdam, but if I were wearing an upper denture, I would want all the retention possible. A proper seal will certainly do no harm. We should have no quarrel with any technique which gets results, and it is well to know several ways of handling particularly difficult cases.

Lateral palatal seal areas: The lateral palatal seal areas are located on the flexible tissue between the hard median area of the palate and the maxillary ridges, and they extend from the rugae bilaterally to the posterior palatal seal. An examination of anatomic dissections indicates that this seal will not cause pressure on the posterior palatine nerve and blood supply. What has been considered a relief area can be utilized for added retention. The only contraindication would be the presence of bony spines. If present, they must be relieved, but these cases are not common.

Maxillary ridge: The maxillary ridge bears most of the stress of the upper denture, and often it can carry maximum stress without discomfort. However, most of these ridges are limited in the amount of pressure they can take comfortably. Preservation of as much ridge as possible at the time of extraction is very important. There should be fewer alveolectomies and a minimum of trimming done. Patients with extreme maxillary protrusion are among the few situations where surgery is indicated prior to denture construction. As a rule, high arches are preferable to flat ones. With good muscle-trimmed impressions, proper sealing, the correct centric relation recorded at the proper vertical opening, and a balanced occlusion free of all cuspal interference, there should be little difficulty with any complete upper denture. Good esthetics and phonetics usually go together with ridge position and function.

The Mandible.—

Retromolar pad: The retromolar pad is an important landmark, for the posterior end of the lower denture should rest upon it. The denture should cover all of the pad unless there is interference with the upper denture because of large tuberosities. In many patients, interference would mean that the vertical opening had not been correctly established. Stability and the ability to withstand stress

are increased in proportion to the area covered by the lower denture, providing there is no functional interference with the muscle attachments.

External oblique ridge: With the exception of muscle attachments, the external oblique ridge should form the lateral boundary of the lower denture in the molar region. It is between the crest of the mandibular ridge and the external oblique ridge that the greatest stress of mastication is borne. A special tray used in making the lower impression should extend at least within 2 mm. of the external oblique ridge.

Buccal frenum: The buccal frenum and the attachment of the buccinator muscle are in the buccal vestibule; these should be checked because this is the narrowest part of the lower denture, and interference here will cause instability of the denture.

Labial frenum: Though very prominent and attached near the crest of the ridge, the labial frenum should seldom be eliminated by surgery. A good impression allowing for functional movements of it is all that is necessary.

Mylohyoid ridge: The mylohyoid ridge is usually covered by very thin mucosa and may require relief. For this reason, the lingual flange should end at the ridge or be made thick enough to allow for relief, if needed. The denture should not extend more than 2 mm. below the mylohyoid ridge if there is an undercut. It is along this ridge that the muscles of the floor of the mouth are attached, and most dentures will be more stable if the lingual flange ends at the mylohyoid ridge.

Lingual frenum: The lingual frenum is either cordlike or fan-shaped and requires functional freedom. The sublingual salivary glands and the papillae (submaxillary caruncles) through which they empty are located near the lingual frenum, and extreme injury and soreness can result from interference with them.

Torus mandibularis: The torus mandibularis is a bony prominence which may or may not be present on the lingual surface of the mandible, usually in the region between the positions of the first and second bicuspids. It is not a bone tumor nor is it pathologic in structure. It will not stand pressure and must either be relieved or removed surgically.

Mandibular ridge: The mandibular residual ridge is seldom favorable or ideal, and it is frequently knife-edged, flabby, or flat. This is just one of the reasons why lower dentures are more difficult than upper dentures. Trimming of sharp points of bone is sometimes indicated, but usually major surgery should be avoided where possible.

PREDENTURE CONSIDERATIONS

A complete history of the patient's denture experience should be obtained. From this we can determine what the patient is expecting and what trouble has been experienced with previous dentures. It pays to be discriminating in our choice of denture patients. The psychologic factor is just as important as the physical problems, and often more so. Our chances of success must be determined by us before we accept the patient. In our limited way, we should psychoanalyze every prospective patient. By this, I do not mean to put them on a couch. We need only to classify them according to mental types, based on past experience. House[1]

classifies his patients' mental attitudes as (1) philosophic, (2) exacting, (3) hysterical, and (4) indifferent. The first two classes are favorable and the second two are unfavorable. A denture practice can be very happy, satisfying, and remunerative, but not if we take every patient that is referred to us. It is not our professional duty to wreck ourselves physically and financially in attempting the impossible. Remember that once we start a case it is our responsibility until the patient is satisfied. Fortunately, there are not many of these impossible patients, but just one occasionally is too many.

An examination chart should be filled out or some written record made of all facts pertaining to each patient.

Roentgenograms of the edentulous ridges should be made to locate unerupted teeth, root fragments, foreign bodies, or any residual pathologic areas. A prognosis and proper advice as to surgery should be given to the patient. Healthy, comfortable ridges are the best foundations for our dentures. The patient's general health as influenced by mouth conditions is also our responsibility.

Study casts are usually valuable aids in discussions with patients. If the work is to be done, these casts can be used for the construction of special impression trays. For this reason, great care should be taken in making the preliminary impressions, making sure that they cover and record all the necessary areas. Usually the fee is not quoted to the patient until the second visit after a detailed study has been made of the diagnostic chart, roentgenograms, and study casts. The fee for this diagnostic service is absorbed in the cost of the dentures, if we make the dentures.

With all new patients, the financial arrangement should be half down and the balance on delivery of the dentures. This may not be necessary with patients for whom we have done similar work before and their record has been satisfactory. Dentures that are paid for never give the patient or the dentist much trouble. A fee for adjustments should always be charged after the initial adjustment period is over. We cannot afford to adjust dentures free for life, and it is not our responsibility

Good dentures are worth much more than the average dentures. We should give our patients the very best possible and charge them accordingly. Too many men are charging the same for dentures today as they did 10 or 20 years ago. Can you buy a new car for the same price as then? Good dentures take time to construct, and the dentist deserves a good fee for making them.

IMPRESSIONS

What constitutes a good impression? I am not going to discuss techniques, for there are many good ones. The definition of an impression in the Glossary of Prosthodontic Terms[2] is as follows: "A negative registration of the entire denture-bearing, stabilizing, and border seal areas present in the edentulous mouth." With some dentists, border molding seems to have gone out of style, but along with the majority of the prosthodontists, I believe that border molding is still considered a fundamental part of good impression making.

VERTICAL DIMENSIONS

Vertical Dimension.—"A vertical measurement of a face with which is correlated the distance between the upper and lower dentitions or the residual ridges."[2]

Physiologic Rest Position.—"The mandibular position assumed when the head is in an upright position and the involved muscles, particularly the elevator and depressor groups, are in equilibrium in tonic contraction, and the condyles are in a neutral unstrained position."[2]

Rest Relation.—"The relation of the mandible to the maxillae at which there exists in all of the muscles involved a state of balanced tonus. The rest relation of the mandible exists when all of the muscles involved are in a state of balanced tonus, but the degree of jaw separation in rest relation is dependent on the sagittal inclination of the head."[2] In other words, if the head is too far forward, the rest relation will result in a shortened vertical dimension, and if the head is too far back, it will result in an increased vertical dimension.

Free-way Space or Interocclusal Distance.—"The distance between the occluding surfaces of the maxillary and mandibular teeth when the mandible is in its physiologic rest position." In other words, "A measure of the distance between rest position and occluding position."[2]

Vertical Dimension of Rest Position.—"The vertical measurement between the two jaws that exists when the mandible is in physiologic rest position . . . the vertical measurement of the face when all of the muscles attached to the mandible are in a state of tonic contraction only."[2]

Vertical Dimension of Occlusion.—"The vertical measurement of the face when the teeth are in occlusal contact . . . the vertical separation of the mandibular residual or alveolar ridge from the maxillary residual or alveolar ridge and the resultant facial profile as established by occlusal contacts . . . the vertical face length as established by the contacts of teeth or occlusion rims."[2]

Obtaining these relations correctly is fundamental to good denture construction, but the methods of obtaining them are many and varied, and their accuracy is affected not only by the method used but also by the skill and judgment of the operator in use of the particular technique chosen. Accuracy of the result is the thing that is most important.

Three formulas relating to vertical dimensions to think about and remember are: (1) Vertical Dimension of Rest Position minus Free-way Space equals Vertical Dimension of Occlusion; (2) Vertical Dimension of Occlusion plus Free-way Space equals Vertical Dimension of Rest Position; and (3) Vertical Dimension of Occlusion plus Centric Relation equals Centric Occlusion.

Physiologic rest position is best obtained when the occlusion rims are not in the mouth. A small triangular piece of adhesive tape is placed on the cheek by the side of the nostril and on the side of the chin. With calipers, the distance between these points is measured when the head is in a vertical position, unsupported, and the muscles of the mouth are relaxed. The patient is directed to say *M* several times, and then the distance between the points is measured. The patient is engaged in conversation, then his talking is stopped, and the measurements are repeated. Do not tell the patient what you are doing, as he may become self-conscious and alter his position. The rest position must be determined before the vertical dimension of occlusion is recorded by closure on wax occlusion rims. This will be approximately 3 mm. less between the points than the distance when the mandible is at the physiologic rest position. This difference will provide approximately 2 mm. of

clearance between the occlusal surfaces in the molar region when the mouth is in repose. These measurements can be varied for esthetic reasons, and sometimes a compromise must be obtained between esthetics and function. If corrections are made in the vertical dimension, the patient may have to adjust to new muscle habits which will require conscious effort for a time. The vertical dimensions may also be measured from the gnathion to the subnasion by means of a profile guide or calipers.

If the patient is wearing old dentures, study the physiologic rest position and free-way space (interocclusal clearance) of these. Also study the esthetics, and compare the facial appearance with any photographs which are obtainable. If the vertical dimension of occlusion needs to be increased, determine the amount and measure the distance. The vertical dimension of occlusion should then be established at this point. Judgment based upon experience will help determine the proper vertical opening for each patient, for there is no infallible rule.

REGISTRATION RECORDS OF CENTRIC, PROTRUSIVE, AND LATERAL RELATIONS

Centric relation is "the most retruded relation of the mandible to the maxillae when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movement can be made, at any given degree of jaw separation."[2]

Centric relation may be recorded by various methods. The accuracy of the result is more important than the method of recording it. There are theoretical and practical errors connected with all known methods, and the perfect method has not yet been found. However, there are many good methods which, if done correctly, will give good results. We should select one which we can execute with consistently good results. There is often theoretical condemnation of techniques, even though the practical results are excellent.

The Gothic arch (needle point) tracing, whether it is a tracing made extraorally or intraorally with either a stylus, a needle point, a central bearing point, or a chew-in with tracing studs against modeling compound, does make a record of the direction and envelope of movement of the mandible in the horizontal plane. How it is interpreted and how much of it is used is dependent upon the desires of the dentist. "The apex of a properly made tracing is considered to indicate the most retruded unstrained relation of the mandible to the maxillae which is centric relation."[2] This may then be recorded with plaster, wax, or modeling compound. The principle of the tracing is embodied in the use of many different devices used in securing maxillomandibular relations. Other methods involve the use of wax interocclusal records made while the mandible is guided to the desired position. It is necessary to make protrusive and lateral interocclusal records in order to adjust many of the articulating instruments. The more accurately the instrument is adjusted, the less adjustment of occlusion will be required at the chair to bring the dentures to acceptable balance. It is possible to complete upper and lower dentures which will be so accurate in occlusion that the dentures will function in the mouth precisely as on the articulator, and very little adjustment will ever be required when the dentures are worn.

The use of the Gothic arch tracing as a guide when recording centric, protrusive, and lateral relationships is considered to be the most accurate by many, while some think they can guide the mandible arbitrarily to an accurate centric relation. They have no *proof* of the exact mandibular position even though the mandible may be in the correct centric position. It is possible to use a hinge axis face-bow or an axis locater to determine when the condyles are in their posterior superior terminal hinge positions.[3] Each dentist has a good method of obtaining centric relation records, but until someone can show me practical results that are superior to those obtained with the guidance of the Gothic arch for denture construction, I expect to continue to use it in combination with central bearing and plaster interocclusal records. The checking of the completed dentures in the mouth is the proof of its accuracy. If they function in the mouth the same as they did on the articulator (after they have been spot ground and milled), it is positive proof that the method of obtaining the relationship and the method of mounting must have been very accurate. We are all hoping for improvements, for there are some disadvantages to every known technique.

We sometimes hear about the fallacy of centric relation, the fallacy of the Gothic arch, the fallacy of the articulator, and the fallacy of balanced occlusion. I think that most of us are going to continue to get good practical results while these proponents are talking about their new theories which are causing so much confusion within the profession. All registrations should be made on stabilized bases which should be as accurate as the finished dentures. The accuracy of the registrations will be lost if the bases do not fit accurately.

In centric relation, the anteroposterior position of the mandible is determined by the posterior terminal hinge position of the condyles. The apex of the Gothic arch indicates the posterior terminal hinge position at a certain vertical opening, and all horizontal movements of the mandible are made forward from this position. Patients wearing old dentures may have, by necessity, acquired a functional eccentric position, but we have never found it necessary to build new dentures anterior to the posterior terminal hinge position or the apex of the Gothic arch. We have followed over 500 patients in study club work and postgraduate classes and have yet to find a patient for whom we had to alter the occlusion from that established in centric relation.

THE IMPORTANCE OF SPLIT CAST MOUNTING

To Dr. J. W. Needles should go the credit for the introduction of the split cast method of mounting casts on an articulator. Its use should be included in any list of fundamentals of denture construction. It is useless to develop accurate centric and balanced occlusion on an articulator and then lose them in the flasking and curing process. If the articulator has been adjusted by the use of accurate relationship records made on accurately fitted bases, the errors, which are unavoidable in processing, can be eliminated. By remounting on the other half of the split casts and using selective spot grinding and careful milling, keeping the incisal pin in position to serve as a stop to prevent closure from the established vertical opening, these corrections can be made accurately. Balanced occlusion will be good from

the moment the new dentures are inserted, as can be proved by checking with articulating paper or ribbons. Little, if any, correction in occlusion will be required after the dentures are worn, and sore spots will not develop as a result of occlusal interferences.

SPOT GRINDING, MILLING, AND RECARVING THE OCCLUSAL ANATOMY

When they are first remounted, the dentures are spot ground only in centric position until the incisal pin nearly touches. The use of three colors of articulating ribbons is a very great aid. Red, purple, and green typewriter ribbons can be cut into short strips of the desired length and handled with cotton pliers when they are used. The purple strips are used for centric position, the red is used for left lateral and green for right lateral positions. By this method, you can determine which surfaces should be ground. It is necessary to learn to analyze what we see, keeping in mind that centric occlusion must not be destroyed. Wherever possible, the cusps are preserved, unless one or more of them extend farther occlusally than they should. To check lateral occlusion, only the cusps on the working side are marked first. Only the buccal cusps of the upper teeth and the lingual cusps of the lower teeth are ground in this occlusal position. These cusps never touch in centric position so the vertical dimension of occlusion will not be decreased, and the efficiency of centric occlusion will not be disturbed. The formula is B-U-L-L—buccal of the uppers and lingual of the lowers. Lingual of the lowers applies to the lingual cusps of the lower teeth on the balancing side also. The cusps which are important in mastication are: *the lingual cusps of the upper teeth* which occlude between the buccal and lingual cusps of the lower teeth, and the *buccal cusps of the lower teeth* which occlude between the buccal and lingual cusps of the upper teeth. These are the cusps which contact in centric position preserving the vertical opening. They are the pestles which contact in the mortars of the opposing occlusion. Mortar is not a good word, for instead of being a cup-shaped cavity, the convex working cusp should occlude between convex cusps and convex transverse ridges whose surfaces are made more efficient by supplemental grooves. The mesial and distal slopes of all the cusps may be flat gliding surfaces but all other contacting surfaces should be convex.

Protrusive and lateral balance should be checked and corrected, and there should at least be simultaneous contact between the anterior teeth and between the molars with a gliding contact to centric position. I think most prosthodontists still prefer to see a better balance than just a three-point contact. Esthetics of extreme protrusive or retrusive cases may preclude the possibility of protrusive balance, but these are exceptions and cannot be dealt with by rule any more than can those cases with extreme variance in the width of the arches. Balanced occlusion is important more for comfort between meals than for efficiency in function. Food between the teeth means a space until there is tooth-to-tooth contact.

After spot grinding has been completed, the surfaces will be somewhat uneven and there will not be the minute harmony of contact which should exist. A minimum of milling may be done with abrasive paste without impairing the efficiency of the teeth, and comfort will be greatly increased.

Recarving the occlusal anatomy is a step that is often neglected. The teeth have been carved individually to the functional range of the patient by spot grinding and milling. Where the anatomy of the posterior teeth can be improved, it should be recarved. The grooves should be deepened, supplemental grooves added, and the cusps sharpened. The sharper the cusps with escapeways between, the more efficient will be the teeth. Point and line contacts between the occlusal surfaces are more efficient than smooth, flat contacting surfaces. Slight polishing should be done after the teeth have been recarved.

THE TEMPOROMANDIBULAR JOINT AND THE HINGE AXIS

There are several theories about the physiology of the temporomandibular joint, but what is more important to us is how its function affects the methods we use in denture construction. Is the hinge axis of the mandible important and is it fundamental to denture construction?

The answer depends upon what degree of accuracy is required. Machinists can work to varying degrees of tolerance—to as little as 1/1,000 of an inch or even 1/10,000 of an inch. Tolerances are set up for every job, as it would be too expensive to make all machinery to the accuracy of 1/10,000 of an inch and, in many cases, it would be of no practical value. It is not necessary to locate the hinge axis to any such degree of accuracy, and some say it is not necessary to locate it at all. Others are satisfied to locate it anywhere within the circumference of the condyle. It is easy for all of us to find valid reasons to back up our theories. If it were very difficult and time-consuming to locate the hinge axis at a point, I would say that it might not be worth the time required for complete denture work. However, it is very easy to do, and I do consider it a valuable technical step, prior to mounting the casts.

If you have not tried to locate the hinge axis, you should make a few experiments for yourself with a mandibular hinge axis locator. Most of the equipment for this purpose has been so heavy, so complicated, so expensive, and so unavailable that very few men have ever used it or have even watched it being used. The techniques of McCollum, Stewart, Granger, Downs, Lauritzen, Thompson, and others are of no value to us unless we make use of them in our practice. Some are afraid it is too complicated to use and feel that they need personal instruction which is not readily available.

At present, there is probably a greater difference of opinion and a wider variety of theories of occlusion than at any time in the history of prosthetic dentistry. When those who are supposed to know are so far apart in their theories, how are we to know which are the best and most accurate methods? We all have our own theories based upon what we have been taught plus what we have learned from practical experience and any reading and research which we have done. We probably have taken some postgraduate courses and may also have been members of study clubs. All of this, plus an inquiring mind, should make us want to try some of these things for ourselves. We will find some theories that we agree with and can use and many we will discard. An important part of a professional man's education is to learn to have an open mind and a desire to investigate theories

and their practical applications. We will then be in a better position to do our own thinking and possibly contribute a few new ideas of our own. Theories must be practical in order to be of value, and their practical application must not be too difficult and time-consuming.

Locating of the hinge axis is not difficult, and its relative position to the casts can be transferred to the articulating instrument quite easily. The hinge axis of the instrument will then correspond to the hinge axis of the patient and variations in the opening component will produce a more accurate result. This applies to the cusp rise for lateral and protrusive movements as well as to increasing or decreasing the vertical dimension of occlusion.

It is important that the condylar guidances of the articulator be attached to the upper member of the instrument, if opening the instrument is not to change the condylar guidance readings. There are variations between the anatomic temporomandibular joint and the condylar guidances of most articulators. The variation for the amount of the path that is used in function is very slight, and its effect is probably not noticeable on complete dentures, but Stuart has even gone so far as to make individual condylar guidances to fit each case. Granger has made a series of condylar guidances for his instrument from which he can select those closest to condyle paths of the patient. These variations are much more easily detectable on natural teeth. We should be perfectionists, but practical too, and the question is how far in complete denture work is it practical to strive for perfection in the reproduction of mandibular movements. We go a lot further today than formerly, and the results are certainly better. The perfect denture has never been built, but there is a marked improvement in finished dentures made with exacting techniques.

We have seen enough demonstrations by Kurth,[5] Downs,[6] and others to prove to us that the chewing stroke is not horizontal, but elliptical in the vertical plane. This has been valuable research which has put an end to many arguments and has started a lot of new ones. We have all heard the saying, "enter bolus, exit balance." This is correct, but it should not constitute an argument against balanced occlusion.

Patients may be able to chew just as well with dentures that occlude only in centric position as they could with dentures that not only occlude in centric position but also are balanced in eccentric positions. Some dentists would lead us to believe that our patients can chew better with dentures that are not balanced. Schweitzer[7] has given us a very fine analysis of the Transograph and Transographic articulation. I do not know whether he agrees with part or all of the theory of articulation or whether he agrees with the claims to accuracy of the Transograph. These are his conclusions, "An attempt has been made to present the theory and practice of Transographics. Although it claims very few original ideas, its concept and instrument represent something new and intriguing. It is entirely different from our traditional ideas. There is a big difference between the Transograph and conventional articulators. One must open his mind to receive these concepts without being prejudiced by personalities. Our profession has never had any fear in being exposed to new theories. As time goes on, it will be able to evaluate this one."[7]

Trapozzano[8] wrote an excellent discussion of the article by Schweitzer[7] and took exception to many points. I feel sure that there are many more exceptions he would have taken to the theory and the claims that are made for the instrument had he been given more time. Trapozzano's conclusion was, "In closing, I would say that *any* of the concepts and techniques which have been or are being used are open to considerable criticism; however, I am left with the feeling that Transographics promises much more than it delivers."[8] I would like to see the dental profession open-minded to all new theories and investigate them thoroughly. What I object to is to have the inventor of the Transograph pose as an authority and discredit the works and theories of men who have contributed far more to the progress of prosthetic dentistry than he has. He has introduced confusion by misleading statements such as, "The Fallacy of Centric Relation,"[9] "The Condyle Paths have no value."[10] He proves these to his own satisfaction, but he would be surprised how few he has actually convinced. These are part truths, but he puts his own interpretation on the answers and that which is to be accomplished. What confusion we would have if all dentures made by any technique except Transographics would have to be made over because of their inaccuracies.

Suppose, for argument's sake, that dentures that do not have balanced occlusion in lateral and protrusive ranges should be equal to or even slightly more efficient according to chewing tests. I do not agree that they are, but if so, the patient will still not be as comfortable with the dentures nor will he have the freedom from sore spots. The dentures are used not more than 10 per cent of the time for the mastication of food, and the other 90 per cent of the time the teeth contact more or less intermittently and in various positions. If bruxomatic movements are pathologic, then it would follow that the barn door hinge is superior for it has no such movements. All articulators are supposed to be in error when adjusted to reproduce eccentric movements.

From a practical standpoint, I decided to see what my patients thought of this idea, without telling them what I was doing. I remounted dentures for three patients on the articulator by the split-cast method after they were cured and spot-ground them only into centric occlusion. Ordinarily, I would have spot-ground and milled them also in lateral and protrusive occlusions before delivering them. I asked the patients to wear them for a few days first. After a week, I spot-ground and milled them in lateral and protrusive positions, and you should have heard the comments from all of them. There is no doubt in my mind that eccentric movements of the mandible are functional and not pathologic as has been stated.

Exacting, discerning patients expect and have a right to that freedom from interference in occlusion which makes for greater comfort in the 90 per cent of the time when they are not eating.

It seems to me that these new theories or concepts of occlusion have tended to confuse the profession as to the importance of balanced occlusion. I think that Downs[6] has given us one of the finest coordinations of theories that we have had. His work shows as conclusively as that of Kurth[5] and others what the actual movements are in mastication, but he goes much further than the others, including the proponents of Transographics. He demonstrates the importance of balanced occlusion and the use of the hinge axis as an aid to accuracy in obtaining it.

In the opinion of practically all of the leading prosthodontists, balanced occlusion has been and still is the most important of all the fundamentals of denture construction. How we obtain it is not so important, but some method should be used that will successfully accomplish the result in the finished dentures if we are to give our patients the kind of service to which they are entitled.

There are four requirements which every satisfactory denture should fulfill:

1. Esthetics—The natural appearance of the teeth and gums and a pleasing, natural expression of the face.
2. Phonetics—Dentures that are an aid rather than a hindrance to good speech.
3. Efficiency—The ability to properly masticate food.
4. Comfort—The result of good retention, good stability, and a good balanced occlusion on bases with equalized pressure on the denture-bearing areas.

SUMMARY

I would like to repeat the objective which I stated at the beginning of this article. It has been the translation and transmission of information and inspiration which I hope has helped your evaluation of the confusion and contradiction which is now prevalent among our prosthetic leaders.

Stanislaus said, "To believe with certainty we must begin by doubting." If we accept what we hear without confirmation, we know nothing with certainty. A little research and much thinking is good for all of us. Sir Leslie Stephen said, "The only way in which one human being can properly attempt to influence another is encouraging him to think for himself." Those who are able to do their own thinking should not allow others to do it for them.

And, last, a quotation from Bourke Cockran, ". . . there is but one road to success, and that is merit. The man who is successful is the man who is useful. Capacity never lacks opportunity. It cannot remain undiscovered, because it is sought by too many, anxious to use it."

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IMPROVED PHONETICS IN DENTURE CONSTRUCTION

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THE THREE MAJOR FACTORS in complete denture construction are mechanics, esthetics, and phonetics. Considerable progress has been made in improving mechanics and esthetics, but little has been done to improve phonetics. Neglect of this major factor in denture construction may be attributed to the fact that most edentulous patients tend to return to normal speech after a postinsertion practice period of several days to several weeks. A variety of oral inaccuracies occur during this practice period, but by far the most common, as well as the most difficult to overcome, is the mispronunciation of the *S* and *SH* sounds. While faulty speech is tolerated as part of "getting used to" the denture, it causes embarrassment to the patient and adds to his burden of physiologic adaptation to the denture.

In the Air Force, faulty speech is intolerable when it concerns the flyer or control tower operator, because failure to speak distinctly over the intercommunication system could be hazardous to craft and crew. Flyers and control operators are not immune to dental diseases, and some of them lose a sufficient number of teeth to warrant replacement. In the prosthetic treatment for this group, phonetics becomes an acute problem. Therefore, the objective of the present investigation was to develop a procedure in denture construction which would enable the patient to speak clearly at the time of insertion of the denture.

The literature in dental prosthetics was reviewed, and previous methods for improving phonetics were evaluated. Snow, after observing many casts of natural dentitions, pointed out that a tracing which started at the vault and passed over the lingual alveolar area to the incisal edge of the maxillary incisor always formed a reverse curve. He recommended thickening and contouring the area lingual to the collars of the maxillary incisors of the denture in order to reproduce this reverse curve, and he maintained that this reproduction facilitated the pronunciation of *S* and *SH*. Landa uses the labio-dental sounds *(F* and *V)* as an adjunct to the arrangement of the maxillary anterior teeth. He believes the teeth should be arranged so that these fricatives can be pronounced easily and naturally. Landa also maintains that proper vertical dimension is the key to proper pronunciation of *S* and *SH*. Sears reports that clearer *S* pronunciation will result from fashioning the area of the anterior median ridge according to the type of tongue. He recommends making a groove in this area for the broad tongue with a slight median sulcus and the building of a ridge in this area for the tongue with a deep median

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A portion of the data in this report was presented in a thesis, The Utilization of Palatography in Complete Denture Construction to Facilitate Articulate Speech, in partial fulfillment of the requirements for the degree of Master of Science at Washington University, St. Louis, Mo., June, 1950.

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sulcus. Sears also advocates making a palatogram on patients whose median sulcus of the tongue does not coincide with the midline. Pound believes that the entire lingual aspect of the maxillary denture should be contoured to simulate the normal palate, if proper phonetics is to be attained. Many authors recommend the reproduction of the rugae as an adjunct to proper phonetics. Probably the oldest and most widely used procedure for improving speech is the thinning of the entire lingual surface of the maxillary denture in order to create more space for the tongue.

The literature in phonetics was perused, with special attention given to tongue positions in phonation. A moment's reflection of elementary physics recalls that all that is required to produce sound is a source of energy and a vibrator. The source of energy for the voice is expired air from the lungs, and the vibrator is the margins of the vocal folds in the larynx. As air passes the highly sensitive vocal folds, appropriate portions of the margins vibrate to produce the desired sound. This sound is modulated by the larynx, the laryngeal pharynx, the pharynx and the nasopharynx, the nose, and the oral cavity, all of which act as cavity resonators to give resonance to the voice. Further modulation is brought about by the articulation which takes place between the vocal folds, the velum and the pharynx, the tongue and the velum, the tongue and the hard palate, the tongue and teeth, the lips and teeth, and finally the lips themselves.

The tongue plays a major role in speech. It changes position and shape for the pronunciation of each of the vowels, and it is the principal articulator for the consonants. In pronouncing the consonants, the tongue contacts various portions of the teeth, the alveolar ridge, and the hard palate. Since these structures are either replaced or covered by the denture, it was basic to the study to know exactly which portions of these structures are normally contacted by the tongue in pronouncing a given consonant. To accomplish this, palatograms were made on a group of dentulous individuals, with normal speech, who were chosen so as to incorporate a maximum variety of tooth arrangement, tooth occlusion, arch form, arch size, vault form, and vault depth.

PROCEDURE FOR MAKING PALATOGRAMS FOR THE DENTULOUS SUBJECTS

A uniformly thin artificial palate of methyl-methacrylate resin was constructed for each subject. The palate was inserted and tested for retention and adaptation. The subject practiced speaking with the palate in place until speech became clear. Trial tests for the palatogram were made by having the subject pronounce a given sound and open his mouth without again contacting the palate with his tongue. The palate was then removed, thoroughly dried, dusted with nonscented talcum powder, and carefully inserted in the mouth. The subject was then asked to pronounce the previously practiced sound, and the palate was carefully removed and examined. The moist tongue removed the powder from the area of contact, leaving a clear tracing (palatogram) on the artificial palate (Fig. 1). However, after a short period, this area dried, and the tracing became obscure. In order to preserve the palatogram for future study, the contact area was outlined with a glass-marking pencil immediately after the palate was removed from the mouth.

PALATOGRAMS FOR VOWEL SOUNDS

Palatograms were made for all the vowels, and in studying and comparing these, it was found that there is tongue contact with portions of the palate in pronouncing all the vowels except *O*. Therefore, in making palatograms of the consonants, the *O* was used in combination with the consonant to be studied, even

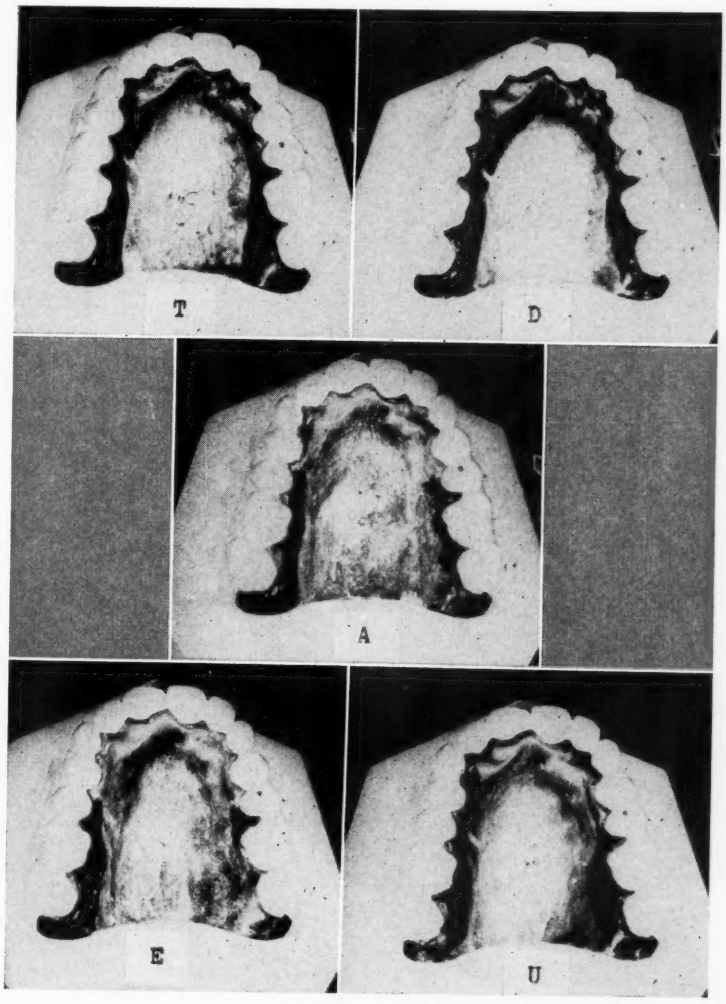

Fig. 1.—Palatograms of the vowel sounds.

though the combination did not result in a standard word. Consonants alone could not be used, because the pronunciation of any of the consonants involves two or more sounds, and therefore, two or more tongue positions; e.g., to pronounce *S*, the *E* sound is made, followed by the characteristic *"SSS"* of the *S*. One has only to pronounce *S* slowly to prove this to be true. The same *E* sound precedes the *F*, *L*, *M*, and *N*. In pronouncing *T*, the "tuh" is made first, followed by the

E. The same *E* follows *B, C, D, G, P, V,* and *Z*. In order to avoid primary or secondary contact, the *O* was used in combination with whatever consonant was studied.

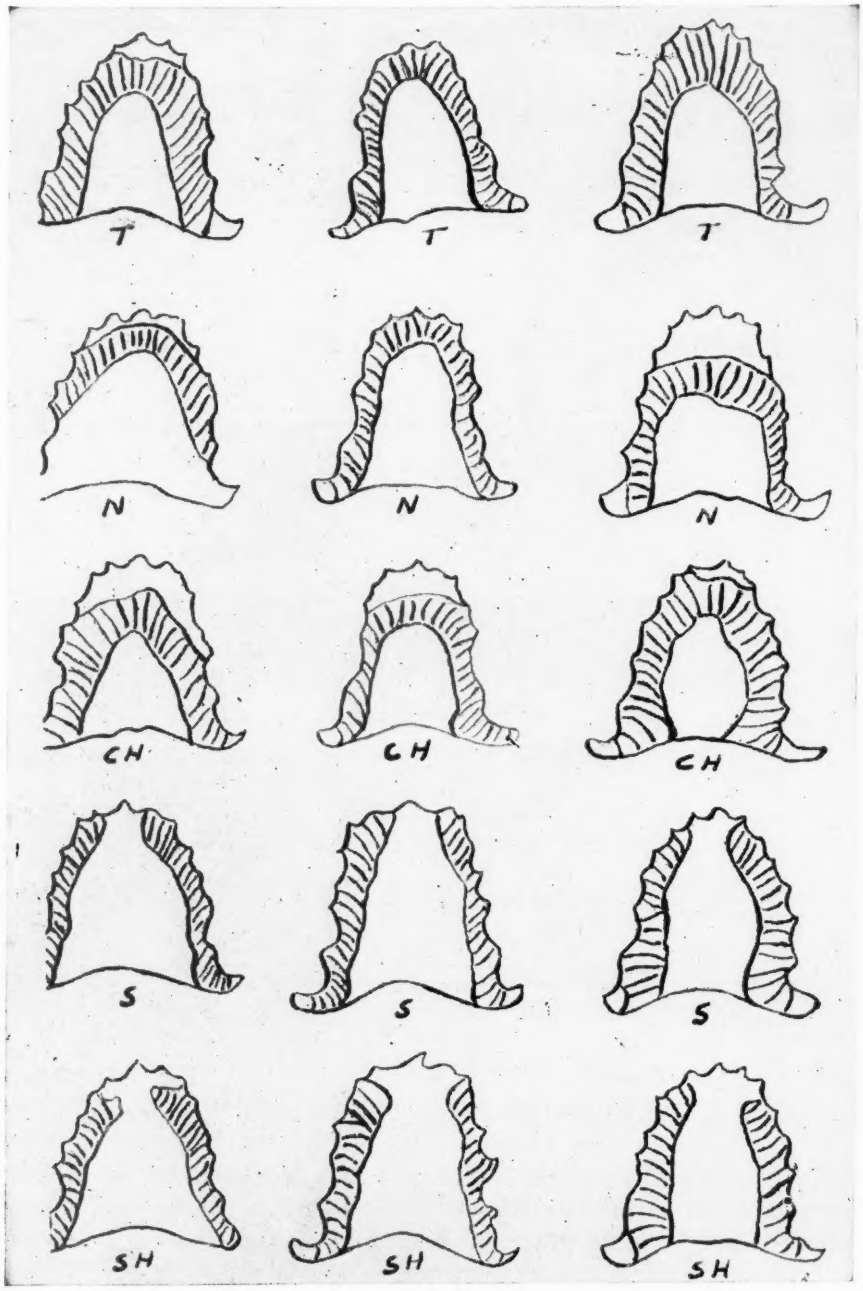

Fig. 2.—A comparison of tongue contact areas on palatograms made on three subjects while making the same sounds.

PALATOGRAMS FOR THE CONSONANTS

Palatograms for all the consonants were made and filed for study. In studying and comparing the palatograms of the same consonant pronounced by different members of the group, it was found that no two persons contacted exactly the same area in pronouncing the consonant, but that a sufficient similarity existed to constitute a pattern (Fig. 2). The patterns for the *T, D, N,* and *L* were not distinct individually, i.e., it was not possible to look at a palatogram and determine which of these consonants had been pronounced in making the tracing;

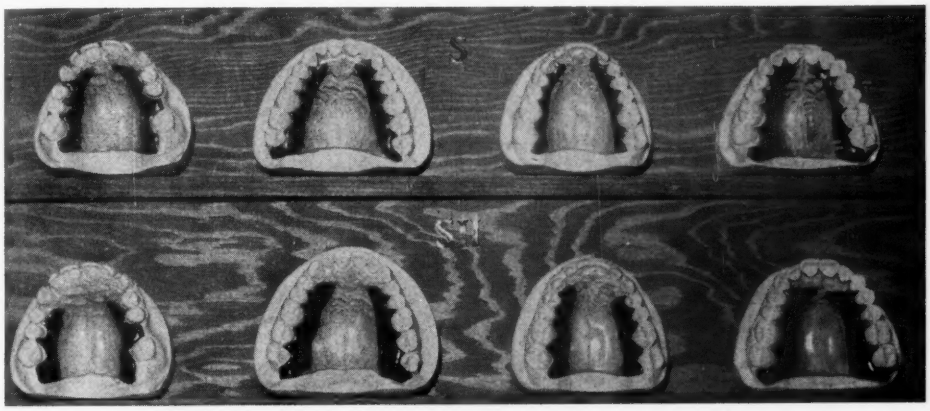

Fig. 3.—Palatograms of *S* and *SH* sounds.

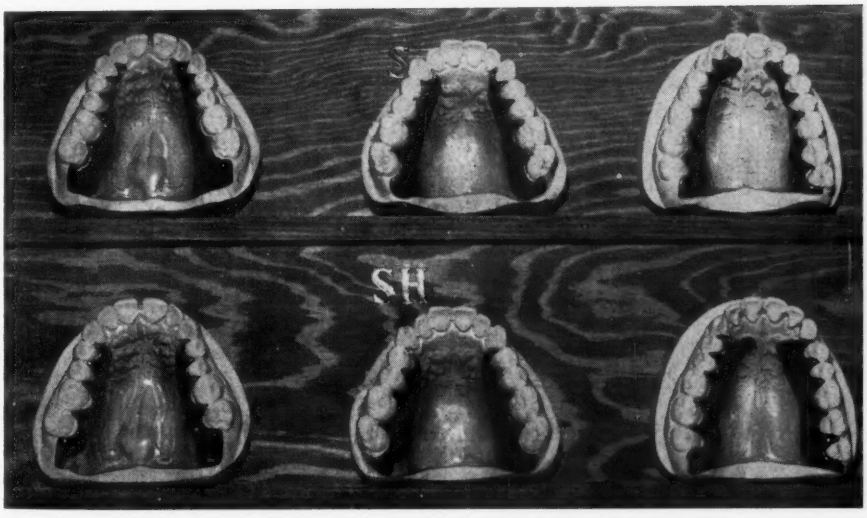

Fig. 4.—Palatograms of *S* and *SH* sounds.

however, the group pattern for these consonants was sufficiently distinct to be certain that either the *T, D, N,* or *L* had been pronounced in making the tracing. A comparative analysis of the palatograms of the *S* and *SH* was of particular interest, because each of these presented an individual similarity and constituted a distinct pattern (Figs. 3 and 4).

THICKNESS OF THE PALATE

Over 500 palatograms were made, and by the palatographic study, we were able to obtain a definitive picture of tongue palatal contact for the pronunciation of the vowel or consonant. In order to test the areas most sensitive to thickness, various portions of the artificial palate were thickened in increments of 1 mm. of wax. The addition of 1 mm. in the anterior region (from cuspid to cuspid) made speech awkward, difficult, and indistinct. The addition of 1 mm. thickness in the posterior alveolar area made speech awkward but not indistinct. The entire vault area could be filled with wax up to the outline of tongue contact without interfering with speech (Fig. 5).

The next phase of the investigation consisted of incorporating this information into a procedure for artificial denture construction.

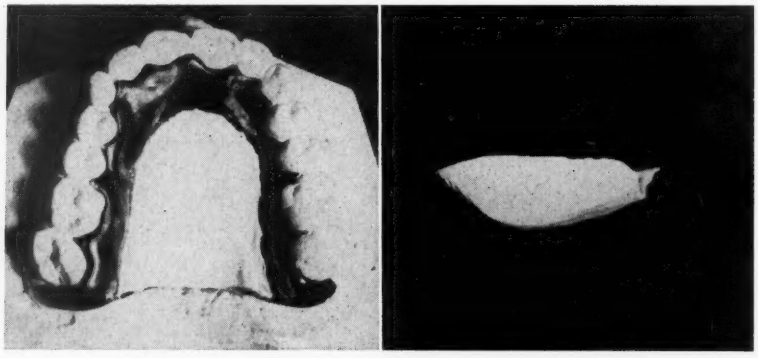

Fig. 5.—Modifications of palate contour. *Left,* Wax is added in the vault. *Right,* The thickness of wax added in the vault.

PROCEDURE FOR THE EDENTULOUS GROUP

In the first part of this phase of the investigation, no effort was made to be selective in choosing subjects. The criterion was that the subject be edentulous and physiologically ready for prosthetic treatment. The application of the palatographic study was started while the dentures were in the waxed, "try-in" stage and after satisfactory esthetics, correct centric relation, proper vertical dimension, and balanced occlusion had been attained. The mandibular trial base was waxed to completion in the usual manner, and the final waxing was done on the labial and buccal aspects of the maxillary trial base. The waxing on the lingual surface of the maxillary trial base was confined to the area immediately adjacent to the teeth, with a minimum of wax added to assure a smooth surface between baseplate and collars of the teeth (Fig. 6). The mandibular trial base was then placed in the subject's mouth, after adhesive powder had been sprinkled on the tissue surface to insure maximum retention and stability. Nonscented talcum powder was dusted on the lingual surface of the maxillary trial base, and the base was carefully seated in the subject's mouth. The subject was then instructed to pronounce the con-

sonant to be studied. The trial base was carefully removed from the patient's mouth, and the area of tongue contact was outlined with a glass-marking pencil (Fig. 7). The outlined area was waxed, contoured, redusted, and another palatogram was made. This procedure was repeated until a normal tongue palatal contact was established.

To develop a normal pattern, it was always necessary to thicken the outlined area. Sufficient thickness was usually obtained by the following procedure: waxing was started around the first molar; enough wax was added to create a 1 mm. margin around the collar of this tooth. The area between this margin and the pencil line on the palate was then filled with wax and smoothed (Fig. 8). Next, enough wax was added around the delineated anterior teeth (those included in the tracing) to allow a 0.5 mm. margin at the collars. The area between this

Fig. 6. Fig. 7.

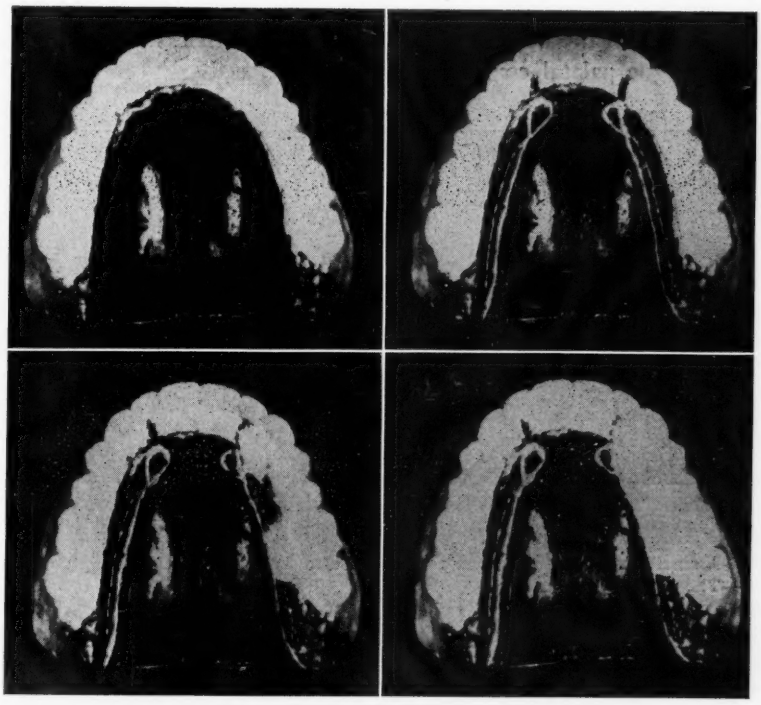

Fig. 8. Fig. 9.

Fig. 6.—A denture wax preparatory to making a palatogram.

Fig. 7.—The area of tongue contact is marked on the denture and wax is added as required to develop normal tongue contact for the specific sound desired.

Fig. 8.—Wax is added in the molar and anterior regions.

Fig. 9.—Waxing around the anterior teeth is completed.

margin and the anterior palatal line was waxed and smoothed (Fig. 9). Waxing of the bicuspid area was accomplished by adding wax between the palate line and the collars of the bicuspid teeth in sufficient quantity to present an even contour be-

tween the anterior and molar waxed areas. Waxing was completed by adding sufficient wax between the palatal line and second molar to present an even contour between the waxed first molar and posterior border of the baseplate.

In some cases, contouring the tongue palatal contact area to simulate the normal was all that was required for the proper pronunciation of *S* and *SH;* however, most cases required the addition of a small amount of wax in the area of the incisive papilla to prevent the jet of air emitted through the median sulcus of the tongue from escaping toward the vault (Fig. 10). The completed lingual wax-up is shown in Fig. 11.

The final phase of the investigation consisted of studying tongue palatal contact of denture wearers who had faulty speech. The speech inaccuracy in all of these cases was mispronunciation of *S* and *SH*. The mispronunciations fell into two categories: in the one, there was a continuous *S*, so that the speech resulted in a whistling when the *S* was pronounced; in the other, there was an indistinct *S*, which resulted in the *SH* sound when the *S* was pronounced. Palatograms were made on this group in the usual fashion. It was found that, in all cases, there was an abnormal tongue palatal contact.

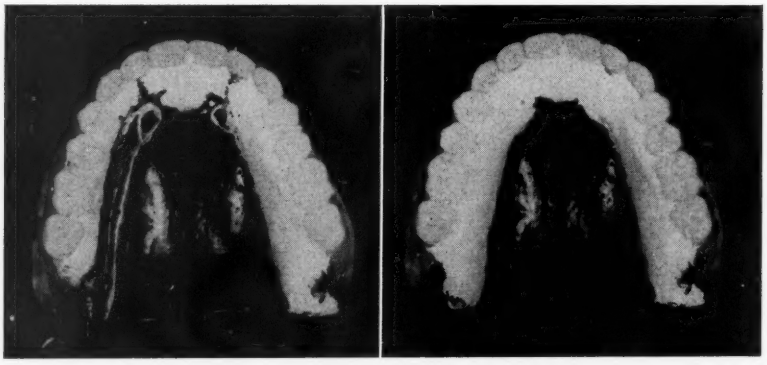

Fig. 10. Fig. 11.

Fig. 10.—A small amount of wax was added in the region of the incisive papilla.
Fig. 11.—The completed wax-up.

OBSERVATIONS

A thin, well-adapted artificial palate (about 1 mm. thick) does not greatly impair normal speech. In making the speech test prior to making the palatograms for the dentulous group, it was found that only a few minutes of practice were required by most of the subjects to enunciate properly. It was also noted that during this short practice period, the *T, D, N,* and *L* sounds were more awkward to pronounce that the *S* and *SH* sounds.

A study of the palatograms showed that, in pronouncing the consonants, the primary area of tongue contact is the alveolar area, and that only a small portion of the hard palate is involved. In a comparative analysis of the *S* and *SH* palatography, it was interesting to note that the rugae area was contacted slightly in

some cases and not at all in others, but that in all cases, the entire posterior alveolar area was always contacted. It was further noted that the rugae area was only slightly involved in the pronunciation of the *T, D, N,* and *L.*

It was found that in order to develop a normal tongue pattern for the *S* and *SH* sounds in the maxillary denture, it was always necessary to thicken the posterior alveolar area.

DISCUSSION

Many clinicians have successfully used the reproduction of the reverse curve as recommended by Snow to improve the pronunciation of *S* and *SH.* Experiments showed that this procedure has merit in that it prevents the jet of air emitted by the median sulcus of the tongue from escaping toward the vault; however, it was found that, in some instances, the reproduction interfered with the pronunciation of *T, D, N,* and *L* and occasionally interfered with anterior lateral tongue contact in pronouncing *S.* To avoid these possible interferences, thickening was confined to the region of the incisive papilla.

The use of the labio-dental sounds as recommended by Landa is a prudent procedure for arriving at proper arrangement of the anterior teeth, and the proper vertical dimension which he recommends for *S* pronunciation certainly is important. However, all too often, after arriving at the proper vertical dimension, faulty pronunciation of this consonant is still evident.

Sears' method of grooving the area of the anterior median raphe for the tongue with a slight median sulcus was found to be helpful in some cases. However, thickening the lateral alveolar areas to produce normal tongue contact tends to increase the median sulcus of the tongue and allows a jet of air to be emitted normally. Sears' suggestion of making a palatogram on cases in which the median sulcus does not coincide with the midline is excellent and is an added reason for the use of palatography to improve phonetics in complete denture construction. In the palatographic study of the dentulous group, it was found that the median sulcus and the midline did not coincide in 20 per cent of the subjects studied. The lack of coincidence is greater in the edentulous subjects because, for esthetic reasons, the maxillary central incisors were set according to the face midline rather than to the palatal midline.

Pound was successful in improving phonetics by contouring the entire lingual aspect of the maxillary denture to simulate the normal palate. However, most of us do not possess the dexterity to approximate Pound's craftsmanship. In this investigation, it was found that good results could be attained by thickening the areas necessary to produce normal tongue contact without meticulous carving and contouring.

SUMMARY AND CONCLUSION

Palatograms were made on a group of dentulous individuals who had normal speech and presented a variety of tooth arrangements, tooth occlusion, arch form, arch size, vault form, and vault height. A comparative analysis of the palatograms

indicated that no two persons contacted *exactly* the same area in pronouncing a given consonant, but that a sufficient similarity existed to constitute a pattern. The patterns for the *T, D, N,* and *L* sounds were not distinct; i.e., it was not possible to look at a palatogram and determine which of these consonants had been pronounced in making the tracing. However, the pattern for these consonants as a group was distinct, so that it was possible to look at a palatogram and be certain that either *T, D, N,* or *L* had been pronounced.

The patterns for the *S* and *SH* sounds presented an individual similarity and constituted a distinct pattern. The pattern for the *S* sound begins approximately in the region of the lateral incisors and bilaterally includes most of the posterior alveolar region. The pattern for the *SH* sound begins approximately in the cuspid region and bilaterally includes all of the posterior alveolar area and some of the vault. In a comparative analysis of the *S* and *SH* palatography, it was found that the rugae area was contacted slightly in some cases and not at all in others, but that in all cases, the entire posterior alveolar area was always contacted. It was also found that the rugae area was only slightly involved in the pronunciation of *T, D, N,* and *L.*

The area most sensitive to thickness is the anterior alveolar area from cuspid to cuspid. An addition of 1 mm. thickness in this area made speech awkward and indistinct, and an additional 1 mm. thickness in the posterior alveolar area made speech awkward but not indistinct. The entire vault area could be thickened up to the tongue palatal tracing line without interfering with speech.

To develop a normal *S* and *SH* tongue palatal pattern in the waxed maxillary trial base, it is usually necessary to thicken the area outlined by the palatogram. In most cases, it is also necessary to thicken the area of the incisive papilla to prevent the jet of air emitted by the median sulcus of the tongue from escaping toward the vault. It was found that building the tongue palatal contact area to normal and thickening the area of the incisive papilla facilitates proper enunciation and eliminates much of the postinsertion practice period.

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IMPORTANT FACTORS IN ADEQUATE DENTURE OCCLUSION

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DUE TO THE ADVANCEMENTS in the field of complete denture prosthodontics, a student may find much of interest. He may become very "esthetic conscious" or "vertical dimension wise" or he may emphasize individually characterized denture bases even when the patients do not expose the denture base.

All of these endeavors tend to produce better clinical prosthodontic procedures, but they do not necessarily assure excellent, acceptable, biomechanical prostheses. Regardless of all other factors, balanced occlusion is necessary. Without this, no prosthodontic result can be completely satisfactory. Some current techniques offer more drama, but they do not satisfy the requirements for a biologically functioning replacement.

In all phases of restorative dentistry, the final result must always develop into a correct occlusion. The term is synonymous with dentistry.

In complete denture prosthodontics, the dentist has the task of restoring the total occlusion. All structures and records of the lost natural pattern are permanently destroyed. This damage is complicated by pathologic processes. There exists no occlusal vertical dimension, no interocclusal distance, no orientation of the occlusal plane, no cusp form, no centric relation index, no incisal guidance, and usually, no normal tonus of the muscles manipulating the masticatory mechanism.

With these factors evident, the dentist must determine and establish a satisfactory working occlusal pattern. This occlusal pattern is essential for the (1) proper mastication of food, (2) proper equalized distribution of forces on the underlying supporting ridges within their tissue tolerance range, (3) opposing occlusal contacts to maintain adequate vertical separation of the ridges, (4) posterior vertical support to help maintain correct apposition of the temporomandibular joint components, (5) eccentric equalized pressure and balancing contacts, and (6) proper occlusal plane height and width for adequate buccal and lingual exchange of food, and contours to make articulate speech possible.

Continuous balanced occlusal contacts must exist whenever opposing teeth are in occlusion, and teeth must come together on a plane so oriented that it will promote the normal functions of the surrounding movable tissues rather than inhibit their functions. A perfect impression coupled with improper occlusion spells disaster to the supporting tissue, but proper occlusion coupled with fair denture tissue base relations may be adequate. Frequently, obscure discrepancies are present

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due to improper arch and occlusal relationships, and adjustments of the denture bases are ineffective in eliminating the difficulty.

The making of jaw relation records is an intangible clinical process. Centric relation is the objective of clinical achievement. The basic problem is that proper centric relation is extremely difficult to register in a good percentage of patients.

RELATIONSHIP TRANSFER

Many methods of recording jaw relations are in current use in the practice of complete denture prosthodontics. Among these are the dynamic system of the "grind-in" and "chew-in" methods.

These methods involve movement and pressure, invite uneven forces against supporting tissues during the making of interarch relationships and records, and produce errors in the records. These errors encompass leverages, uneven pressures, and variable resiliency problems in underlying supporting tissues. They may also have a tendency to record a protruded component position instead of the centric position. The final result may be questioned in regard to equalized vertical occlusal contact. Such contact is necessary and desired.[1,2]

Positional interocclusal record methods make up the bulk of the remaining techniques. The two most popularly used are: (1) interocclusal records with a central bearing point, and (2) the interocclusal records made between the teeth or occlusion rims.

Wax records varying from "mush-bites" to delicate interocclusal records between opposing artificial teeth are used. Plaster of Paris is used for recording nonpressure relations. Some dentists believe that wax could introduce unilateral forces which would result in tipping and rotation of the dentures with nonuniform pressure exerted on resilient supporting tissues.[3,4] Either of these interocclusal registration methods is preferred over the central bearing method for a more uniform equalized loading of underlying tissues.

Two basic conditions must exist and be registered to accomplish a satisfactory interarch relationship transfer. First, the correct centric relation of the mandible to the maxillae is necessary and, second, it is important that the underlying supporting ridge tissues must be displaced evenly when this relationship is recorded.

TRIAL DENTURE BASE STABILIZATION

No interocclusal registrations of jaw relations can be correctly transferred to an articulator without using accurately fitting recording bases. Therefore, a method of stabilization of the baseplates and occlusion rims is necessary.

Accuracy of fit of the trial denture bases is achieved by utilizing well-adapted shellac baseplates which are corrected with activated plastics after the wax relation rims are affixed. Relief material is used to block out undercuts in the cast so that damage to the cast is minimal. Extreme undercuts may be handled by using a rubber base impression material as a lining. By this means, master cast preservation is assured, and moderate undercuts may be engaged to better the tissue-baseplate apposition and result in better trial denture base stability.

OCCLUSION RIMS

To position the dental arches, a bulk of wax is added to the baseplates to fill the interarch space. Then the vertical space between the arches and the anteroposterior relation of the upper to the lower arch may be measured and recorded.

Balanced tonus or contraction of the muscles controlling the mandible is mandatory when jaw relation records are made. Properly contoured occlusion rims that fill the space left by the loss of the teeth and their associated structures will be least disturbing to the surrounding soft tissues when the relationship transfer is made. The result is a relationship made without critical upset of the neuromuscular balance of the combined musculature.

To fabricate such a base and occlusion rim involves shaping the wax rim anteroposteriorly and buccolingually to approximate the form of the tissues that originally occupied the available space. Chair time expended in the making of jaw registrations is a factor, so an occlusion rim requiring minimal adjustment and alteration is desirable.

CONSTRUCTION OF MAXILLARY OCCLUSION RIM

A wax rim 8 mm. wide is constructed over a fitted trial base in such a manner that the anterior point will fall directly over the center of the labial reflection at the labial frenum. The rim in the cuspid region is contoured to fall directly over the reflection and is on the radius of an arch having its center at the anterior point. The horizontal length of this arch may vary from 18 mm. on small arch casts to 22 mm. on large arch casts, with an average of 20 mm. on average casts.

The posterior segment of the wax rim is formed over the posterior residual ridge with 5 to 6 mm. of it buccal to the ridge and 2 to 3 mm. lingual to the ridge. The distal end of the rim is cut off at the anterior end of the maxillary tuberosity slope and is made parallel to that slope. The occlusogingival height of the maxillary occlusion rim should be at least 12 mm. in anterior region and 10 mm. posteriorly.

The wax rim is reduced 4 mm. in width from the lingual aspect in the anterior region from cuspid to cuspid, and starting from the distolingual posterior segment, a wedge-shaped piece of wax is removed on a line to the newly formed lingual cuspid width point. The wax rim thus developed closely simulates the lost tissue and will require a minimum of changing except for alterations of the occlusal plane (Fig. 1).

CONSTRUCTION OF MANDIBULAR OCCLUSION RIM

The construction of the mandibular occlusion rim is similar to that of the maxillary rim with but a few exceptions. The cuspid radius is slightly less on the mandibular rim, and the posterior portion of the rim is trimmed vertically, anterior to the retromolar pad. The anterior height of the rim is 10 mm. and, posteriorly, it ends at the level of the distal part of the retromolar pad (Fig. 2).

Clinically, these occlusion rims allow for nearly normal soft tissue functions, resulting in minimal disturbance to mandibular positions. When labial and buccal

alteration of the occlusion rims is indicated, it usually will be by a reduction of the bulk of wax. The reduction of wax is quick and clean; whereas, addition of wax is a long and tedious process.

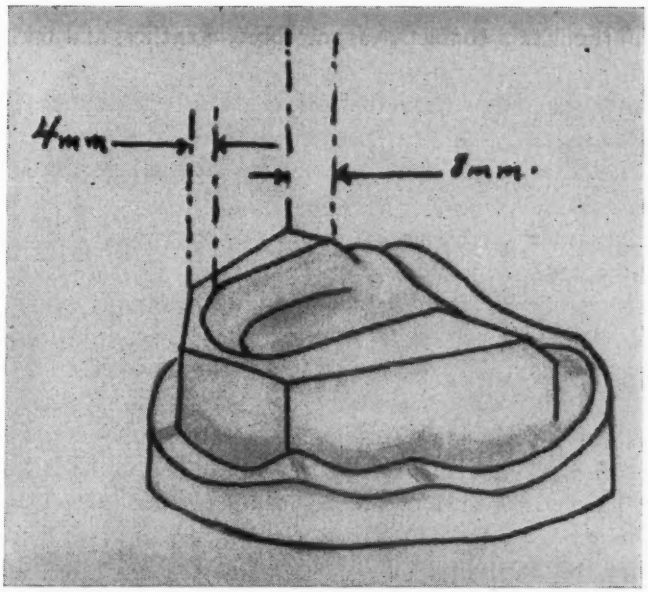

Fig. 1.—The maxillary occlusion rim is constructed to simulate the lost tissue, and when so constructed, it will require minimal adjusting.

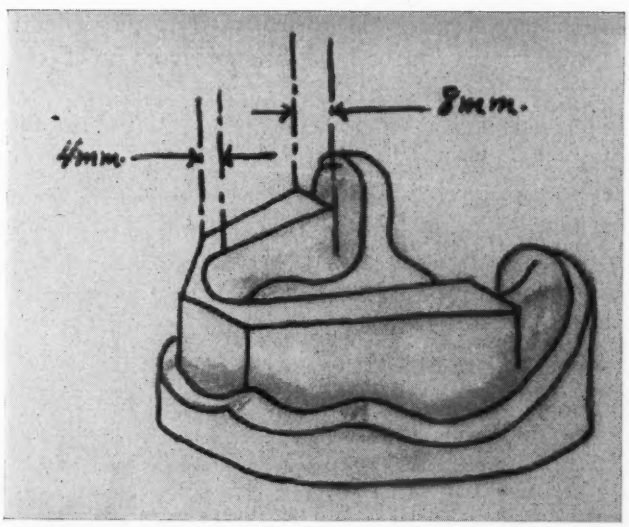

Fig. 2.—The mandibular occlusion rim is developed in a similar manner as the maxillary rim.

ORIENTATION OF OCCLUSAL PLANE

Prior to the transfer of jaw relations, the plane of occlusion should be oriented. This orientation is not a mechanical laboratory procedure since its position influences physiologic functions within the oral cavity. The proper height and width of the occlusal plane is essential for the adequate buccolingual exchange and control of food, speech articulation contacts, tongue space, esthetics, and buccal soft tissue support.

Each patient's occlusal plane is consistent with his oral physiology and esthetic requirement. To orient any plane in space, 3 points must be located. In the denture space, one is located in the anterior region, and one is in each of the posterior segments.

The anterior height of the occlusal plane is determined by the length of the incisal edge of the upper occlusion rim above or below the upper lip while it is in repose and when the lip is properly supported. This anterior height will be even with the relaxed upper lip for the average patient. The height of occlusion rims for patients with long or short lips is at the discretion of the dentist. The two posterior points of orientation of the occlusal plane fall within the height of the distal half of the retromolar pad. The entire plane is parallel to the ridge planes.[5]

When the orientation of the occlusal plane has been established, it should not be changed. Any vertical change in arch relation must take place within the mandibular segment, since the maxillary occlusal plane represents an anatomically fixed plane within the oral cavity.

FACE-BOW TRANSFER

When a hinge axis articulator is used, a face-bow transfer of the relation of the maxillary arch to the condylar axis must be accomplished. This is mandatory in order to reproduce the proper closing arcs of the teeth. The vertical dimension of occlusion may be increased or decreased on the articulator within the confines of the free-way space (introcclusal distance) with no effects on the clinical occlusal result.

The mounting is done with the upper cast positioned so that the occlusal plane is horizontal. The bite fork of the face-bow and the occlusion rim and cast must be supported so that no vertical drop will occur because of the added weight of the cast and the mounting plaster.

CENTRIC RELATION AND VERTICAL DIMENSION

The centric relation transfer records encompass two basic positions. One is the vertical dimension of occlusion, and the other is the anteroposterior and lateral relation in the horizontal plane.

VERTICAL DIMENSION OF OCCLUSION

The edentulous patient can register clinically only one vertical dimension; others are established at the discretion of the dentist. Physiologic rest position is

the basis for all vertical dimensions involved in denture procedures. If there is doubt as to whether or not the patient has retained his correct physiologic rest position, treatment in the form of exercise, mild sedation, and heat may be instituted to aid him in redeveloping the correct position.

With the vertical dimension of physiologic rest determined, the mandibular occlusion rim is trimmed to contact the maxillary occlusion rim uniformly at this vertical distance and at the plane of occlusion. This procedure fixes the proper vertical dimension of occlusion for this position.

Centric relation is recorded at the vertical dimension of occlusion which is always less than the vertical dimension of the physiologic rest position. The vertical difference between the two positions is the interocclusal distance.

Patients must have sufficient interocclusal distance or ultimately the supporting tissues will be destroyed. Two mm. of space between the occluding surfaces in the region of the first bicuspids is the minimum interocclusal distance.[6] Ridge destruction will progress if insufficient space is allowed until a sufficient interocclusal distance is restored. Many authors[7,8,9] have cleared the path for a uniform understanding and application of this important factor. Silverman[10] makes use of the same principle by checking clinically for the necessary and proper vertical speaking space. The speaking space is applied both for proper speech and as a test for an adequate interocclusal distance.

With the vertical dimension of physiologic rest determined, the interocclusal distance may be established by subtraction. To arrive at the vertical dimension of occlusion clinically, wax is cut away from the occlusal surface of the mandibular occlusion rim from one cuspid region to the other. The amount of vertical reduction of the rim is that of the intended interocclusal distance. The occlusal surfaces of the posterior portions of the rim are softened, and closure is made in the mouth until the cut-away anterior portion of the lower rim comes in contact with the anterior portion of the maxillary rim without pressure. This closed position represents the vertical dimension of occlusion, and it is within this interarch space that dentures are constructed utilizing the established occlusal plane.

PRELIMINARY CENTRIC RELATION

Baseplate wax does not exhibit the desired viscosity at flow temperature, so some other type of wax with more desirable properties is utilized to provide a more equalized pressure when the centric relation record is made. Wax is removed from the occlusal surface of the mandibular rim below the existing plane from the cuspid region distally to a depth of 2 mm. In its place, a warm, dead soft wax of low viscosity is added. The vertical dimension of occlusion is registered again with the mandible in centric relation.

Index marks are used on the rims laterally and anteriorly so that re-apositioning may be accomplished for mounting the lower cast. The one disastrous error that may be present in any jaw relation transfer is that of posterior border contact of the bases. Examination of these regions upon removal of the occlusion rims from the mouth is imperative, as any contact spells certain failure. This

centric relation mounting is tentative. The wax interocclusal record does not insure a perfect centric relation mounting. To correct and eradicate these errors, a final check of the centric relation is made at the try-in when all teeth are in position.

TRY-IN

Critical evaluation at the time of the denture try-in is one of the most important clinical procedures in complete denture construction. Its tremendous influence on final denture success has not been given sufficient emphasis.

A cardinal factor to be checked is that of equalized, evenly distributed, proper occlusal contacts of the artificial teeth at the instant of contact in centric relation. An even pressure must be evident over all of the occlusal surfaces. To check this occlusal relation clinically and diagnose its likeness or difference to the same occlusion on the articulator is the basis for the procedure.

To compare the centric occlusion on the articulator with that in the mouth, exact tooth intercuspation on the instrument must be positioned and retained. These intercuspations, when noted clinically by visual or tactile methods, will disclose any occlusal discrepancy. If the centric relation is not correctly recorded, procedures must be initiated to correct it to establish the proper occlusal and positional relations on the articulator.

Another important phase of the try-in is to determine if the correct vertical dimension of occlusion has been established. Clinically, observation of the speaking space seems to be an accurate standard for its evaluation. The "near rest position" sounds and the "near occlusal position" sibilant sounds are checked. Should adequate speaking space be evident, the vertical dimension of occlusion may remain unaltered. If not, it must be corrected.

Regardless of the maintenance or alteration of the vertical dimension of occlusion, some measurement record should be available on the casts to facilitate checking for any vertical change. This is done by placing an index cross on the anterior portion of the maxillary and mandibular casts. The distance between the two crosses is measured and recorded, and this, the vertical dimension of occlusion, may be retained or altered.

CORRECTIVE CHECK-REGISTRATION

Should the clinical, centric relation be in error, a new centric relation record must be made accurately, and it must be proved to be clinically correct prior to the completion of the denture.

A soft, easy flowing wax is the material of choice for making the new record. Plaster and other materials may be used, but they do not exhibit the properties desired to accomplish the desired result. When plaster is used between the occlusion rims, anatomic form, contour, and tactile contact are altered. Foreign, bulky, uncomfortable masses are in the mouth, and the natural reaction to these is one of awkwardness. The use of the wax record made between the occlusal surfaces of teeth, along with proper denture contours, seems to be a more reliable method of

positioning as the natural sensations of tissue contact are maintained. All senses involved in making this record are tactile, and with this tactile sense maintained in an undisturbed state, interocclusal records made between correctly shaped wax denture bases or completed dentures utilizing very slight, equalized pressure are in order. Accuracy of the centric relation record depends mainly upon the tactile sense of the tendons and muscles.

TACTILE REGISTRATION TECHNIQUES

With the maxillary denture positioned in the mouth, a uniformly softened wax segment is placed over the mandibular posterior teeth with its length being just short of the mesiodistal length of the posterior teeth (Fig. 3). No recording wax is placed anterior to the first bicuspid or distal to the second molar.

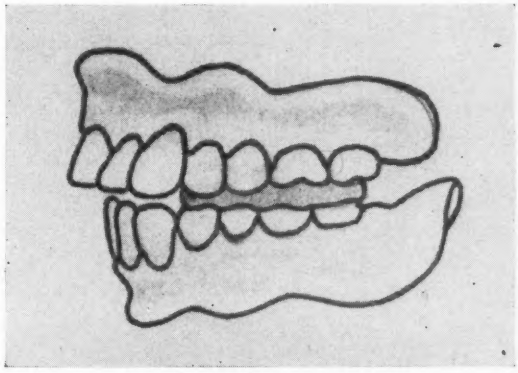

Fig. 3.—The wax is in the correct position for an interocclusal centric relation record.

With the wax warm and easily flowable, the mandibular denture is seated in place. The dentures are stabilized without displacement by the fingers. The patient is requested to *close* his mouth slowly. The words "bite-up" or "bite" should not be used. When the wax contacts the maxillary posterior teeth, the patient is requested to continue closing very, very slowly and to stop closure pressure upon command. Attempts at very slow closure seem to help direct the patient to close in that "most retruded, unstrained position" so desired in registering centric relation. A slight finger pressure on the chin seems to aid the patient, and it may also transmit the tactile sensation of the closure path to the fingers of the dentist. This tactile sensation reveals the relaxation or contraction of the external pterygoid muscles during closure.

Closure is stopped prior to, and just short of, any possible opposing tooth contact. The wax is chilled with air, and the trial denture with the wax index attached is carefully removed. Following cleaning and careful washing, the maxillary trial denture is positioned on the mounted maxillary cast, and the wax index on the mandibular trial denture is fitted accurately onto the maxillary teeth. The trial dentures are luted together for stability during remounting procedures.

Prior to seating and remounting the mandibular cast, the incisal pin of the articulator is lowered (increasing the distance between the upper and lower members of the instrument) approximately twice the distance of the thickness of the wax record in the first molar region. This is done so that after remounting, the upper and lower members of the articulator will again be parallel, and the incisal pin will be flush with the upper member. The first molar region is approximately one-half the radius distance from the condylar axis to the incisal guide pin, so this region will close one-half the vertical amount as that at the site of the incisal guide pin.

Following remounting, the wax index is removed, and the occlusal surfaces of the teeth are cleaned. The articulator is closed to just short of occlusal contact, and the accuracy of the new mounting is determined. To expedite the checking of the accuracy of the new registration, a system is evolved to transfer this registration back to the mouth and discern if it is in the same relationship in the mouth as it is on the instrument. If the two are alike, the new centric relation mounting may be accepted.

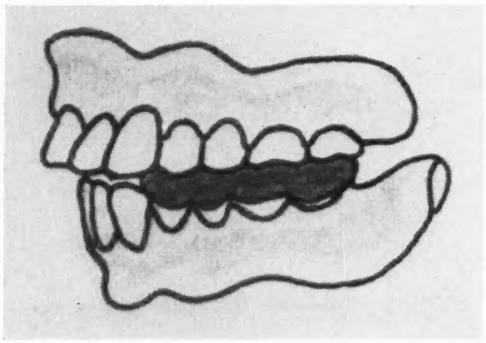

Fig. 4.—The maxillary posterior teeth are closed into soft modeling compound on the articulator to form an index which will be used to verify the new centric relation record.

PROCEDURE TO VERIFY NEW MOUNTING

With the articulator set so that the opposing teeth are just short of occlusal contact, a petroleum jelly film is placed on the occlusal portion of the maxillary posterior teeth. Hot stick modeling compound is dripped on the dry occlusal surfaces of the mandibular posterior teeth. While the compound is still hot and fluid, the articulator is closed so that the occlusal surfaces of the maxillary teeth are imprinted into the soft compound but not through it (Fig. 4). The compound is chilled with the instrument in the closed position.

The articulator is opened, and the mandibular trial denture is removed (Fig. 5). The excess compound on the buccal and lingual surfaces is trimmed off with a sharp knife even with the existing contour. The steep planes created by the lingual surfaces of the maxillary lingual cusps are reduced so as not to drive the teeth abruptly into the centric occlusion index. All debris is removed (Fig. 6).

Fig. 5.

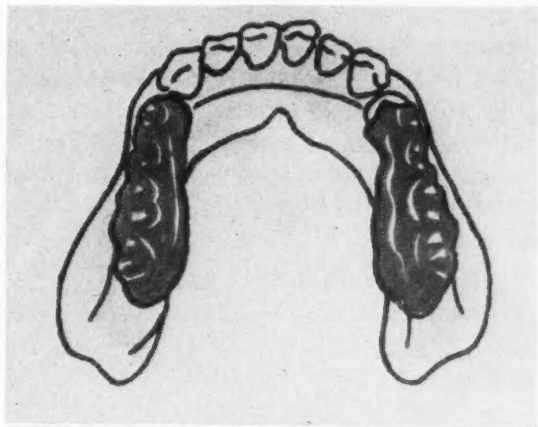

Fig. 6.

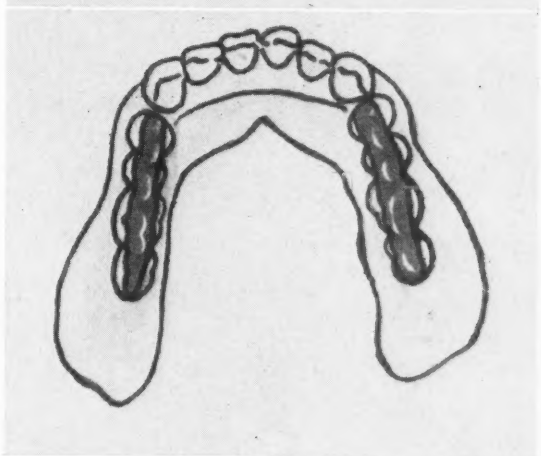

Fig. 5.—The modeling compound index is removed with the mandibular trial denture.
Fig. 6.—The modeling compound index is trimmed to correct the buccal and lingual extensions and to reduce the lingual vertical incline planes.

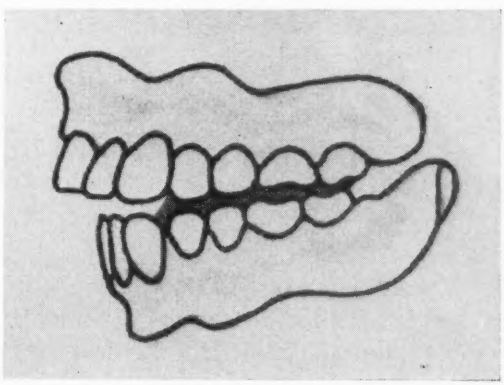

Fig. 7.—The trimmed modeling compound index on the mandibular teeth keys with the cuspal inclines of the maxillary teeth.

The trial dentures are replaced in the mouth, and the patient is instructed to close slowly. If the maxillary cusps contact the entire compound index uniformly without strain or distortion, the registration may be accepted as correct (Figs. 7 and 8). A further check for uniform contact is that of light, rapid, short, tapping of the posterior teeth. When properly executed, this tends to cause the mandible to seek the desired "retruded unstrained position." Should the intercuspation be in error, a new wax interocclusal record must be made, the mandibular cast remounted, the compound index rebuilt, and the trial dentures reinserted in the patient's mouth for another recheck.

After the centric relation record is determined to be correct, the articulator is closed to the level of the vertical measurement between the index crosses on the mandibular and maxillary casts. At this position, the pin should be nearly flush with the upper arm of the articulator. The teeth are now reset into balanced occlusion, and the dentures are completed.

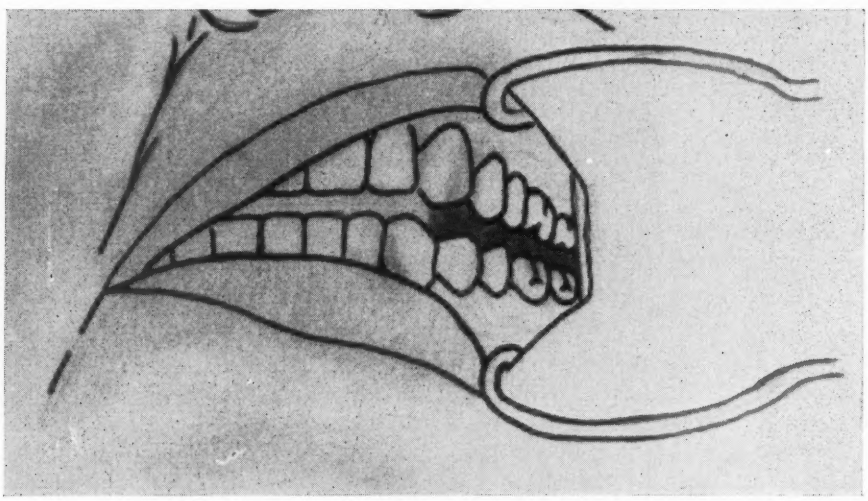

Fig. 8.—The modeling compound index and the trial dentures are inserted in the mouth. If the maxillary cusps contact the entire compound index evenly when the patient closes in centric relation, the remounting record is considered to be correct.

SUMMARY

The opportune time to validate or remake the centric relation record occurs during the try-in stage. At this time, the tactile senses are at their best, and neuromuscular imbalance is minimal. A light, controlled, tactile sense aids in recording jaw relation accurately.

The remounting procedure may be used on completed dentures presenting occlusal discrepancies and is indicated in all cases of tissue trauma where denture base overextension can be ruled out. To destroy the denture base "fit" by so-called relief adjustments only accelerates destruction and loss of the supporting tissues. Only through properly balanced and equalized tooth contacts can the tissues of the

denture basal seat area be preserved. Ignoring this tissue preservation results in no more than a mechanical replacement, not the dental health service entrusted to the prosthodontist.

CONCLUSION

Many accurate jaw registration techniques have been evolved and proved through the years. Some apply to the usage of dynamic concepts and some to static positional concepts. All methods require accuracy and care in their application. No technique may be more accurate than the relative fit of the trial bases utilized. Trial base stabilization is essential in all techniques. Unstrained tactile jaw relation techniques seem to be the most accurate for complete denture success and comfort.

The vertical dimension of occlusion may be determined accurately from physiologic rest position, and it can be verified by speech tests.

Centric relation and centric occlusion must coincide in complete denture occlusion. To verify centric relation, a check-recheck registration index system may be used when the artificial teeth are in position in wax or plastic.

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BALANCING RAMPS IN PROSTHETIC OCCLUSION

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Balanced occlusion is one of the neglected steps in the construction of complete dentures. However, it is essential to their success.[1-5] The average patient learns to use dentures with comparative ease and comfort when the occlusion is balanced. Balanced occlusion makes possible the greatest possible use of masticating power so that food may be properly prepared for digestion.

Teeth which are not arranged in balanced occlusion are merely arranged for the opening and closing mandibular movements. Dentures with this type of occlusion generally destroy the efficient masticating movements habitual to the patient. This is true especially when teeth with high cusps are used on the dentures. Patients with dentures that have unbalanced occlusion lose all definite control of the jaw movements and, consequently, many find it quite difficult to use such dentures. The fact that some patients do learn to use them is a tribute to the marvelous adaptive powers of the human being rather than to the skill of the dentist.

Balancing ramps built in the region of the retromolar pads of the mandibular denture have greatly simplified the procedure of balancing the occlusion (Fig. 1). This applies especially when posterior teeth with zero degree cusps are employed and when the vertical overlap of the anterior teeth is considerable (Fig. 2). When attempting to balance the occlusion of such dentures, one usually has the alternative of sacrificing the balanced occlusion or denying pleasing esthetics to the patient. If esthetics is considered more important, the posterior teeth will not contact in protrusive positions of the mandible, and this lack of posterior tooth contact will cause a tipping of the dentures (Fig. 3).

The occlusion can be balanced very easily in mandibular protrusive excursions when balancing ramps are used, regardless of the vertical or horizontal overlap of the anterior teeth. As the mandible begins to move into a protrusive excursion, the distal marginal ridges of the occlusal surfaces of the most posterior maxillary teeth, usually the second molars, begin to ascend the balancing ramps. Then, when the incisal edges of the opposing anterior teeth are in contact, the distal marginal ridges of the second molars of the upper denture are resting on the most distal portion of the balancing ramps (Fig. 4). The incisors, in protrusive position, are balanced by the maxillary molars against the ramps. The same balancing ramps are made broad enough so that they will balance the den-

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tures in lateral excursions of the mandible. The distobuccal margins of the occlusal surfaces of the maxillary second molars glide along the ramps on the balancing side.

Consequently, the patient can glide from centric occlusion to protrusive occlusion and from left to right lateral occlusions without the discomfort of intercuspal interferences, diminished retention, tissue irritation, and clicking teeth.

Fig. 1.

Fig. 2.

Fig. 1.—Balancing ramps constructed distal to the last molar on the mandibular denture simplify the problem of obtaining balancing contacts in protrusive and lateral jaw movements.

Fig. 2.—Dentures without balancing ramps and with zero degree posterior teeth. There is considerable vertical and horizontal overlap of the anterior teeth.

RAMP CONSTRUCTION

The method of constructing balancing ramps is quite simple. The length, width, and height of the ramps are determined while the occlusion is being balanced. During this procedure, the ramps are built up in wax as far distally and buccally as the last molar of the upper denture will travel in protrusive and lateral excursions. Two millimeters of wax are added to the distal and buccal surfaces of the ramps to allow for polishing and trimming. Then, the dentures are processed in acrylic resin and polished (Fig. 5).

When the completed dentures are tried in the patient's mouth, an interocclusal centric relation record is made, and the dentures are remounted on the articulator. The final grinding, to refine the balanced occlusion, is done on the articulator. When this is accomplished, occlusal cavities are prepared in the ramps. About 1 mm. of plastic is preserved at the border of the ramps (Fig. 6). These two cavities are then filled with silver amalgam, and when the amalgam begins its initial set, the articulator is moved from centric position to

Fig. 3.

Fig. 4.

Fig. 3.—There is no balancing contact on the posterior teeth when the anterior teeth are brought edge-to-edge and when a balancing ramp is not constructed.

Fig. 4.—The distal ridge of the maxillary last molar contacts the balancing ramp when the anterior teeth are brought edge-to-edge.

protrusive position and back, and then from centric position to the left and right lateral positions. These movements are repeated until the upper tooth cuts a path for itself in the amalgam (Fig. 7). The amalgam is allowed to set for 24 hours, and then it can be polished slightly but without creating any heat.

At the insertion of the dentures, a final check of the occlusion in all excursions of the mandible is made. After the patient has worn the dentures for a few weeks, they may or may not settle into the tissues. If settling occurs, the occlusion will no longer be balanced as it was when the dentures were inserted.

Therefore, it would be necessary to remount the dentures on the articulator and rebalance the occlusion.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 5.—The balancing ramps are constructed of wax with a slight excess of height at the time the occlusion is balanced and are processed in acrylic resin along with the denture.

Fig. 6.—Occlusal cavities are prepared in the ramps. Note that they extend far enough buccally to permit balancing contacts during lateral mandibular excursions.

Fig. 7.—The shiny streaks in the amalgam ramps represent the paths followed by the upper last molars during protrusive and lateral jaw movements.

VALUE OF BALANCED OCCLUSION

The moot question often arises as to the value of balanced occlusion when a bolus of food on the working side separates the teeth so far that there is no contact on the balancing side. The reply to this question is simply that the average patient masticates food for only 10 or 15 minutes, two or three times

daily. However, during the remainder of the day, the teeth are in occlusal contact many times in centric and eccentric positions with no food between them, and even during the process of chewing food, the teeth will cut through the bolus frequently, and contact will be made on the balancing side.

The most important reason for providing balanced occlusion is the added retention which it affords to a denture at times when the stability is threatened. Balancing ramps can be an indispensable factor in obtaining this balanced occlusion.

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MODIFICATION OF THE MODEL H HANAU ARTICULATOR AND FACE-BOW

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THE LOCATION OF AXIAL points of rotation of the mandibular condyles, together with the mounting of dental casts on an articulator with orientation in three planes, represents one of the more accurate and highly refined techniques in dentistry. It is useful in difficult cases, not only for diagnosis, treatment planning, and clinical treatment, but also for study and research. These phases are well documented in the literature. Accurate, elaborate, and expensive equipment for the location of axial rotation points and for the anatomic orientation of dental casts is available. With the suggested modifications, owners of the Model H Hanau articulators can increase their scope of usefulness without significant cost. It is also felt that the modification is accomplished simply without loss of accuracy.

ARTICULATOR MODIFICATION

When an orbital pointer is used to orient casts horizontally, in reference to the axis-orbital plane, it is frequently impossible to mount the casts on the standard Model H Hanau articulator because of its short posts (3¾ inches between upper and lower members). Increasing the height of the posts is not new, but is usually done with machined metal shims. Thus, the problem was one of increasing post length 1 inch in a simple manner, using an easily worked, dimensionally stable material of ready availability (Fig. 1). Since the articulator posts are recessed ¼ inch, a plastic shim ¾ inch thick gives the desired 1 inch increase in post height. Clear methyl methacrylate (Lucite) is available in ½ inch and ¼ inch thicknesses. These are easily laminated, using methylene glycol or acetone as cementing media to build up a ¾ inch thickness.

A band saw and drill press make the fabrication relatively simple, although hand tools could be used. A full-sized template (Fig. 2) is used to determine the necessary hole location. A needle-sharp punch, or No. ½ dental bur, can be used to transcribe these hole centers to the plastic. If the holes are drilled 1/32 inch oversize, assembly will be very easy. Otherwise, a minor smoothing of the inside of the holes with a handpiece and vulcanite bur will compensate for minor drilling misalignment. The horizontal condylar markings are also punch-marked onto the plastic shim. These can be made into lines and the degrees marked with a No. ½ dental bur. After scribing, they can be delineated with India ink and covered with a coat of clear nail polish for permanence.

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On some older models of the Hanau Model H articulator, the post has a greater diameter than on the more recent models. For these, the 5/16 inch holes in the plastic shim must be enlarged to a 7/16 inch size.

Also needed are two 2-inch No. 10 machine screws which may be obtained from hardware stores. The two original screws should be labeled and saved for returning the articulator to its original condition, if desired.

In order to insert the plastic shim, the articulator is dissembled as follows: (1) remove the locknut from the bottom of the horizontal condylar adjustment lockscrew; (2) unscrew the post lockscrew; (3) lift off the condyle posts.

The plastic shim is then placed over the inner condyle posts, and the upper parts are replaced. The 2-inch machine screws are used with the original washers to lock the condyle posts for horizontal adjustment. The original locknuts can be replaced on the screws.

ORBITAL PLANE GUIDE

The orbital plane guide is also constructed of plastic (Fig. 1). On the Model H Hanau articulator, a plane parallel to the base and passing through the articulator's condylar axis lies ¾ inch below the upper member of the instrument. A curved piece of the ¾ inch Lucite is used (same as for the post-raising shim). To avoid drilling of the upper articulator member to attach the orbital plane guide, a ½ inch plastic shim (the thickness of the upper articulator member) is placed on one end of the curved guide, and a short parallel holding piece is added. These three pieces are bonded together. They can be drilled and a bolt added for additional strength. The indicator is removable, and one will serve for many articulators.

FACE-BOW MODIFICATION

An orbital pointer and a means of locating axial points of rotation increase the accuracy and usefulness of a face-bow. Kinematic face-bows, of course, have these features. The difficulty arises in using a kinematic face-bow with the Hanau Model H articulator. With the kinematic face-bow, the condyle rods will not move along the "articulator axis" connecting the two axial points of rotation, unless the side arms of the face-bow are of equal length and the bitefork is at a right angle to the face-bow's front arm. In using the kinematic face-bow, the lengths of the side arms are varied and these conditions are not met; the "articulator axis" of the articulator must be extended in some fashion to meet the located axial rotation points. However, these conditions are met with the standard Hanau face-bow, and the condyle rods can be moved in and out on the face-bow and remain on the articulator axis. The problem becomes one of adding an orbital pointer and a means of locating axial points of rotation to the standard Hanau face-bow.

Two face-bows are combined to make one. When the small retaining pin is removed, the condyle rod lock can be removed. The bitefork clamp can then be removed and placed on the second face-bow. This provides a face-bow with two bitefork clamps. The second bitefork clamp will hold a second bitefork

under the mandible for stabilization while the axial points of rotation are being determined (Fig. 3). Also, it will hold a spare articulator pin to serve as an orbital pointer.

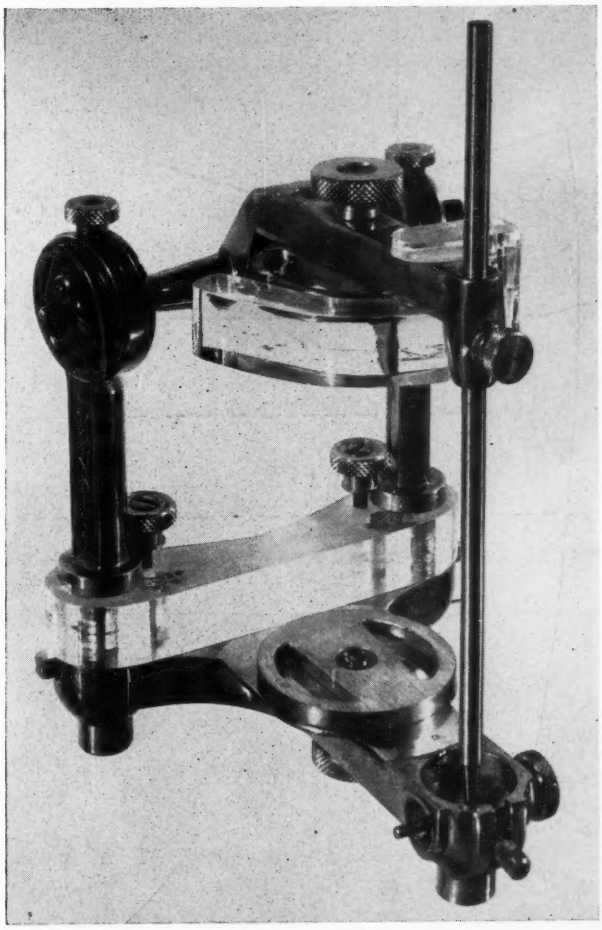

Fig. 1.—A Hanau articulator modified by a plastic post-raising shim and an orbital point guide plane.

The upper parts of the condyle rods are grooved (with a bur or Carborundum disk) so pieces of dead soft iron or copper wire can be inserted in them to serve as rotation point locators. The bitefork which is used under the chin for stabilization should have its tines slightly bent, scored, and modeling compound added to it for the comfort of the patient.

For complete denture patients, one of the biteforks is attached to the lower denture or baseplate. The modeling compound on the other (stabilizing) bitefork is softened, molded under the chin, and held by the second bitefork clamp on the combined face-bow. The face-bow is adjusted approximately, and the

axial points of rotation are located with the dead soft wire pointers (Fig. 3.) The points of rotation are marked on the face, and the wire pointers are retracted. If an adhesive paper ring, of the type used to strengthen holes in

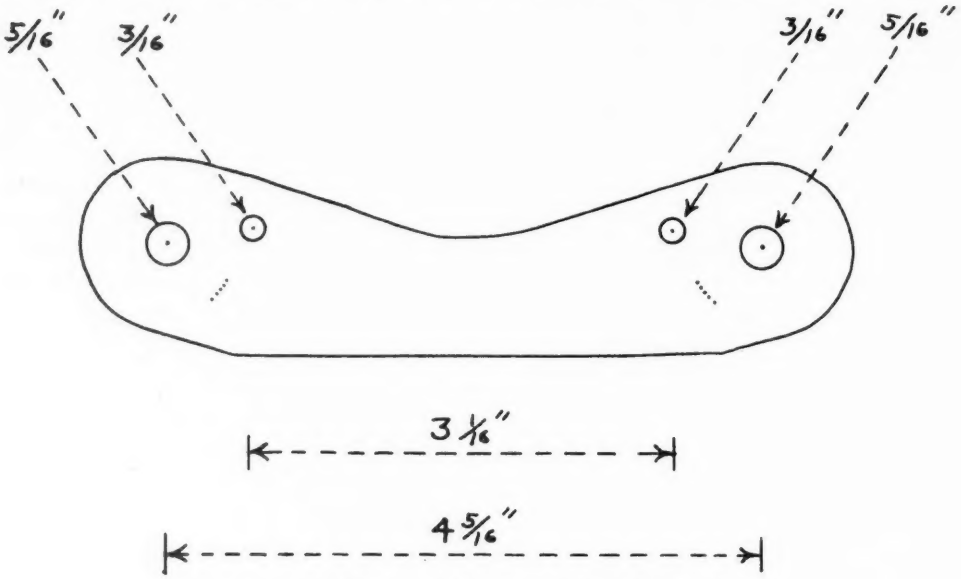

Fig. 2.—A template for making a post-raising shim (half-size).

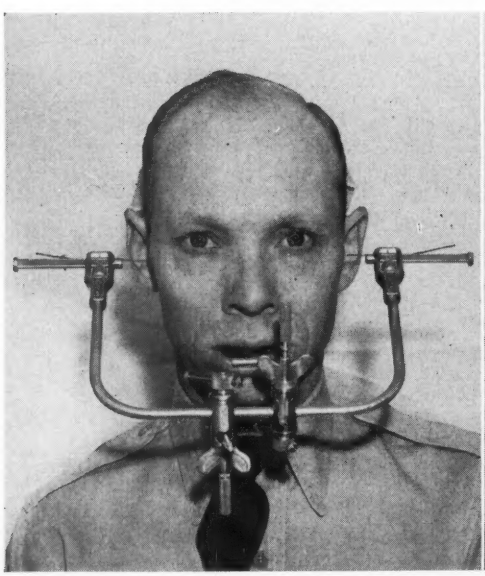

Fig. 3.

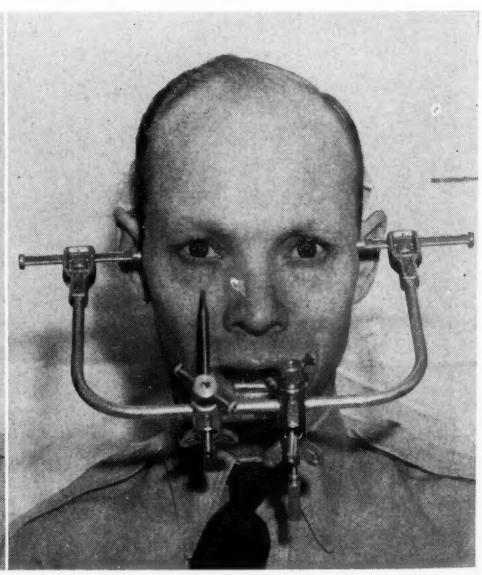

Fig. 4.

Fig. 3.—Dead soft wires in grooves in the condyle rods serve as pointers for locating the hinge axis points. The second bitefork lock holds a second bitefork under the chin to stabilize the face-bow while the rotation points are located.

Fig. 4.—The modified face-bow and the orbital pointer have been adjusted for making the transfer. (U. S. Army photograph.)

ring notebook paper, is placed over the marked rotation point, the standard condyle rod can be adjusted visually with accuracy. The condyle rods are moved in and locked. The stabilizing bitefork is removed and replaced by the articulator pin serving as an orbital pointer. When this is locked in position, indicating the orbital point (Fig. 4), the adjustments are complete. The condyle rods can be moved in or out to adjust the face-bow to the shaft of the articulator in the usual fashion, while the orbital pointer touches the orbital guide plane. This orients the casts in the horizontal plane.

SUMMARY

The prosthodontists' mechanical equivalent of jaw positions and movements is the dental articulator. Orientation of dental casts in three planes and the location of axial points of rotation of the mandibular condyles, with the transfer of this hinge axis to the mechanical axis of the articulator, are aspects of highly refined technique. A procedure has been given by which a widely used articulator can be modified to make these registrations possible. The modifications were made from the standpoint of simplicity, economy, and acceptable accuracy. In addition, no irreversible changes are made in the original articulator.

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CERTAIN OBSERVATIONS ON A COMPLETE DENTURE PATIENT
Part I: Method and Results

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THE PURPOSE OF THIS investigation was to establish if, by electromyographic and other observations, the functioning of the stomatognathic system could be elucidated when complete upper and lower dentures occluded maximally in different mandibular positions. Further, it was proposed to determine if any of the findings noted might be extended to patients with the natural teeth still present.

THE METHOD

A patient in good health, aged 48 years, showing a minimum of oral atrophic change[1] and good muscular co-ordination, was selected for this investigation. He was of a plethoric disposition and well-adapted to his environment. These conditions were calculated to be advantageous as they would not predispose to complicating muscular activity in a stress situation.[2] The oral condition was also good. Well-formed edentulous ridges in normal relationship were covered by a firm mucous membrane having a substantial thickness of lamina propria. It was ascertained that the patient had never suffered from symptoms of a temporomandibular joint arthrosis; visual, palpatory, and auditory examination of both joints gave negative findings. In addition, prior to making dentures, electromyographic records of the resting temporal and masseter muscles were made. Minimal activity was noted, indicative of a healthy muscle pattern.[3] Thus, from the viewpoints of general health, personality, and oral condition, the prognosis for complete dentures appeared ideal. A complete upper denture with 33 degree cusped, porcelain, posterior teeth was constructed, and retention and stability were considered satisfactory. Six different complete lower dentures were constructed with the mandible in different positions; all dentures were made with acrylic resin posterior teeth of a corresponding mold to the porcelain

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Part II: Electromyographic Observations, and Part III: Consideration of the Results from a Neuromuscular Viewpoint will follow in subsequent issues of the JOURNAL OF PROSTHETIC DENTISTRY.

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teeth used on the upper denture.* By the use of a plaster core, the teeth were placed in the same labiolingual and buccolingual relation in each of the seven dentures; this assured the development of similar retentive forces in each denture. Further, the flange extension and form was duplicated in each denture. This flange did not interfere with the action of the facial or lingual musculature. Setting up of the teeth was, in each instance, carried out according to conventional practice, and balanced occlusion was obtained in protrusive and lateral movements.

Six different mandibular positions for maximal interdigitation of the cusps were selected, variations being made only in the vertical and anteroposterior planes; no lateral deviations of the mandible were tested. In each case (with one exception), the mandibular position was determined in the mouth, using a lower retentive acrylic resin base and a hard wax occlusion rim.

The selected positions are referred to throughout this article as (1) anteroposterior variations: muscular (M), retruded (R), artificially retruded (A.R.), protruded (P); and (2) vertical variations: open I (O_1), open II (O_2). In the group of anteroposterior variations, the vertical height of the dentures was maintained constant within practical limits, and this was judged ideal for the patient on the evidence of the rest position of the mandible, phonetics, and appearance.[4] With the two degrees of opening, the anteroposterior position of the mandible was on its functional opening path.[5]

The descriptive terms used to designate the mandibular positions require further definition.

The Muscular Position.—The patient was approached at the jaw relation recording stage in an unhurried manner. As a result of this and his inherent calm disposition, a relaxed state was easily obtained. The rim of the lower occlusion rim was carved to secure an even contact with the upper at an acceptable vertical dimension. When the patient was subjected to suggestion, giving what may be described as a shallow hypnotic state, he was able to open and close so that the vertical line markers on the upper and lower occlusion rims came into exact alignment. Not only was this exactly reproduced at 5-minute intervals on the same day, but it was identical on each of three consecutive weekly visits. Thus, in this case, a reproducible anteroposterior position of the mandible was secured; this is the muscular position, the existence of which is questioned by Moyers.[6] Further reference is made to this point later in the discussion. When, however, the mandibular musculature was relaxed and digital pressure was applied against the symphysis menti by the operator, the occlusion rims occluded with the lower marker line 1.0 mm. distal to the upper rims.

The Retruded Position.—This position was secured by the operator pressing against the mandible with the musculature relaxed. This is a border position but it is accepted as being a bilateral functional position of the mandible. According to Posselt[7] and Rees,[8] further posterior displacement from this position is prevented by ligamentous action about the temporomandibular joints; because of this, it is also a reproducible position.

*Myerson, S.: Personal communication.

The Artificially Retruded Position.—This position was obtained on the Dentatus articulator from a retruded interocclusal registration. The bilateral condylar stops of this articulator (Fig. 1) were each screwed back 1.5 mm. This is equivalent to displacing the mandibular condyle 1.5 mm. posteriorly along the determined condylar path. This position is not reproducible in the mouth, since further posterior displacement from the retruded position is effectively resisted by the joint ligaments. Thus, when closure was made with the denture in the mouth, an even intercuspation did not result, but rather the distal slopes of the upper cusps contacted with the mesial slopes of the lower cusps. As a result of inclined plane action, with stable and retentive dentures, a posteriorly directed force was applied by the condyles against the lateral ligaments of the temporomandibular joints, as upper and lower teeth were brought into occlusion in this position.

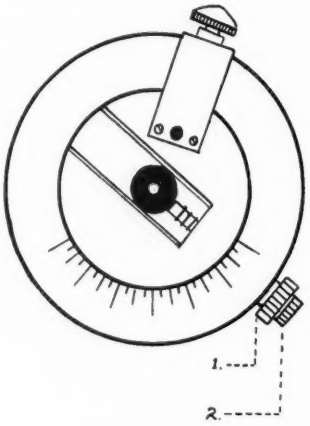

Fig. 1.—The condylar guidance element of a Dentatus articulator. Note that the anteroposterior condylar stop is adjustable by the screw *2* and locked by the locknut *1*.

The Protruded Position.—This position was recorded in the mouth, the anterior displacement from the muscular position being approximately 2.5 mm.

The Open Positions I and II.—Both of the open positions which were used obliterated the interocclusal clearance; the first was at the rest position, and the second effected a further 3 to 4 mm. opening in the incisal area. Since the functional path and the maximally retruded border path diverge on opening, the anteroposterior distance between the retruded position of the jaw and the intercuspal position increased from the muscular position to the first open position, and again to the second open position.

The six different denture positions are superimposed on Posselt's diagram of vertical border and functional paths of the mandible (Fig. 2). Their related positions were measured by two methods.

First, a series of cephalometric roentgenograms, and right and left temporomandibular joint exposures were made. The cephalometric roentgenograms were

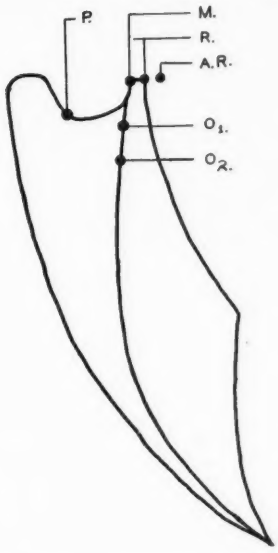

Fig. 2.—The envelope of mandibular movement (after Posselt). The denture positions are: *(P)* protruded, *(M)* muscular, *(R)* retruded, *(A.R.)* artificially retruded, *(O_1)* open to rest position, *(O_2)* open 3 to 4 mm. beyond rest position.

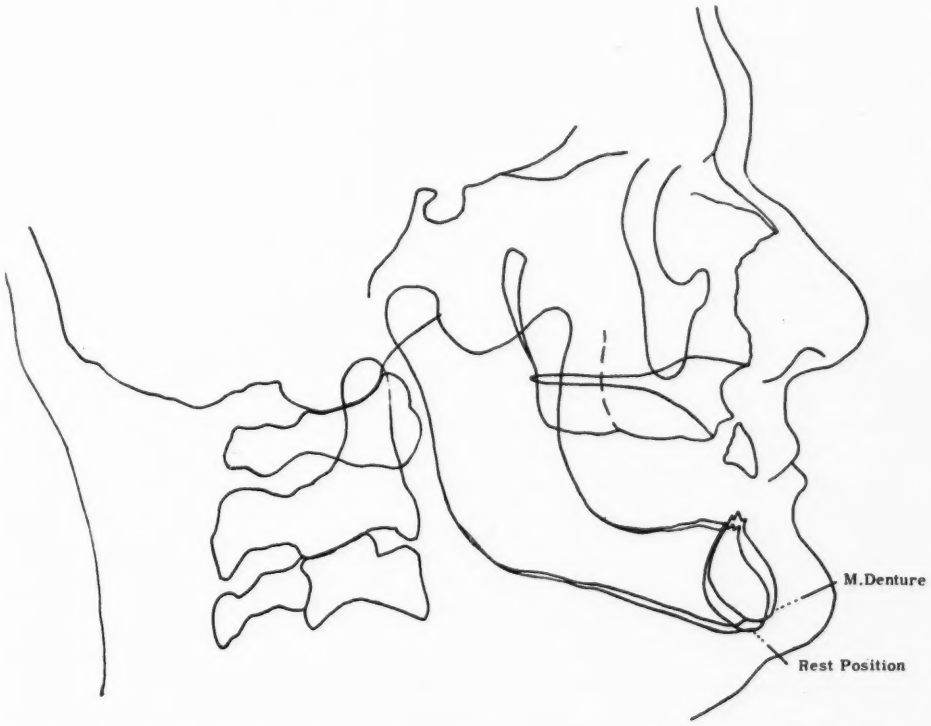

Fig. 3.—Cephalometric tracings of vertical denture positions. Soft tissue profile is with muscular denture.

traced with the aid of a template of the mandible. In the case of the lateral views and the joint roentgenograms, separate templates were made for each condyle. In the latter instance, the existence of two differently shaped condylar profiles could not be traced to traumatic factors and was thought to be entirely developmental. Composite tracings are shown in Figs. 3, 4, and 5, and the condylar

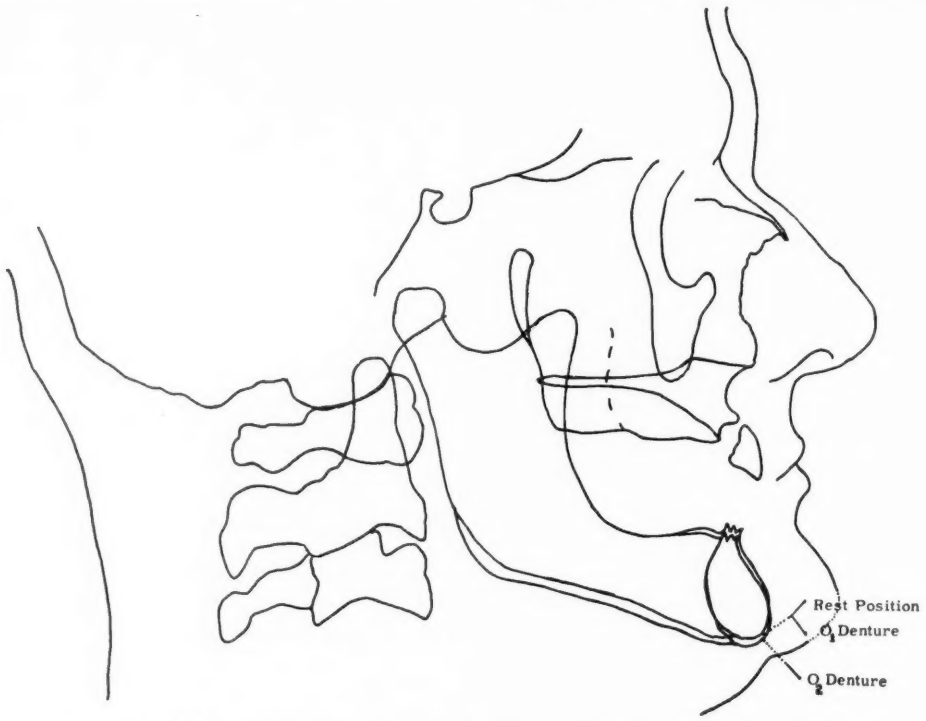

Fig. 4.—Cephalometric tracings of vertical denture positions. Soft tissue profile is of rest position.

position in the glenoid fossae can be estimated from Fig. 6. It is interesting to note, in conjunction with Fig. 6, that there is very little apparent profile change with the different denture positions. However, with each different position, definite and marked anatomic and functional changes have been recorded. Photographs were also taken of the rest and occluded positions with the dentures in place. The soft tissue of the face is a great curtain masking the true picture of structural anatomy and physiology, and that which "appears" or "looks" good may be doomed to failure if function is not considered. For comparison, rest position roentgenograms were also taken without the dentures in place. These were repeated after wearing the muscular denture and the maximally open denture to observe any change in rest position.

Second, measurements were made on the Dentatus articulator with reference to the muscular position denture as zero. Vertical displacements were measured on the incisal pin, and horizontal displacements were noted at the condylar slots, correction being indicated on the basis of the registered condylar angle. The articulator readings are tabulated in Table I.

TABLE I.

DENTURE	VERTICAL DISPLACEMENT	HORIZONTAL DISPLACEMENT
Muscular—M.	0	0
Retruded—R.	+0.5 mm.	− mm. cos. 20°
Artificially retruded—A.R.	+0.5 mm.	−2.5 mm. cos. 20°
Protruded—P.	0 mm.	+2.5 mm. cos. 20°
Open I—O_1	5 mm.	+ 1 mm. cos. 20°
Open II—O_2	10 mm.	+ 2 mm. cos. 20°

+ = anterior to muscular.
− = posterior to muscular.

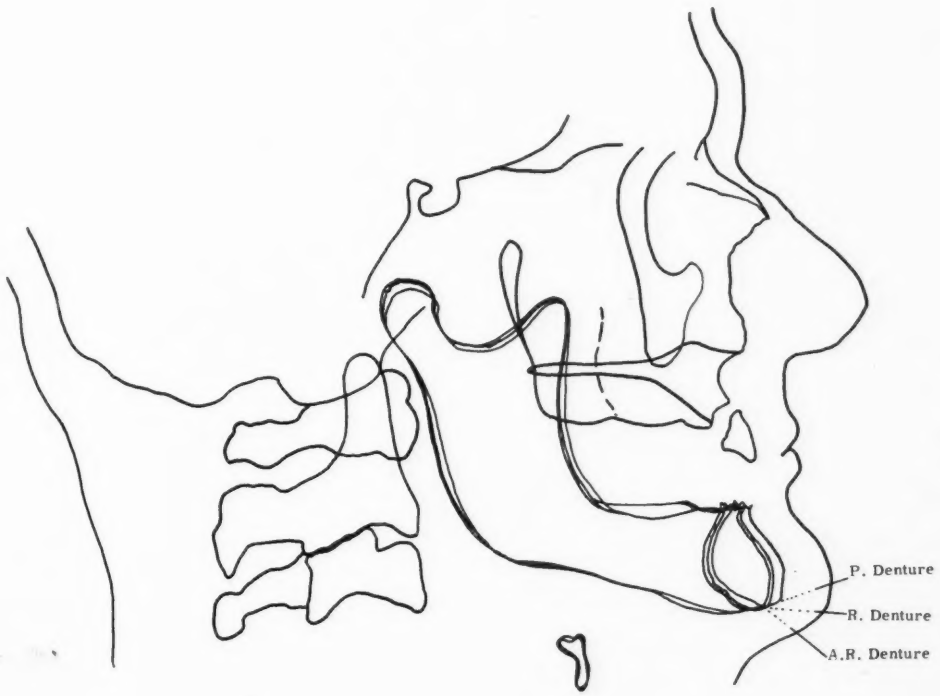

Fig. 5.—Cephalometric tracings of horizontal denture relations. Soft tissue profile is with retruded denture.

After processing in acrylic resin, the lower dentures were equilibrated, first on the articulator and finally in the mouth. In the latter instance, mounted stones were used to obtain an even occlusion in the selected intercuspal position and a good balance in protrusive and lateral excursions.

The patient attended at weekly intervals, as far as possible, for observation and taking electromyographic records. Each denture was worn for a period of

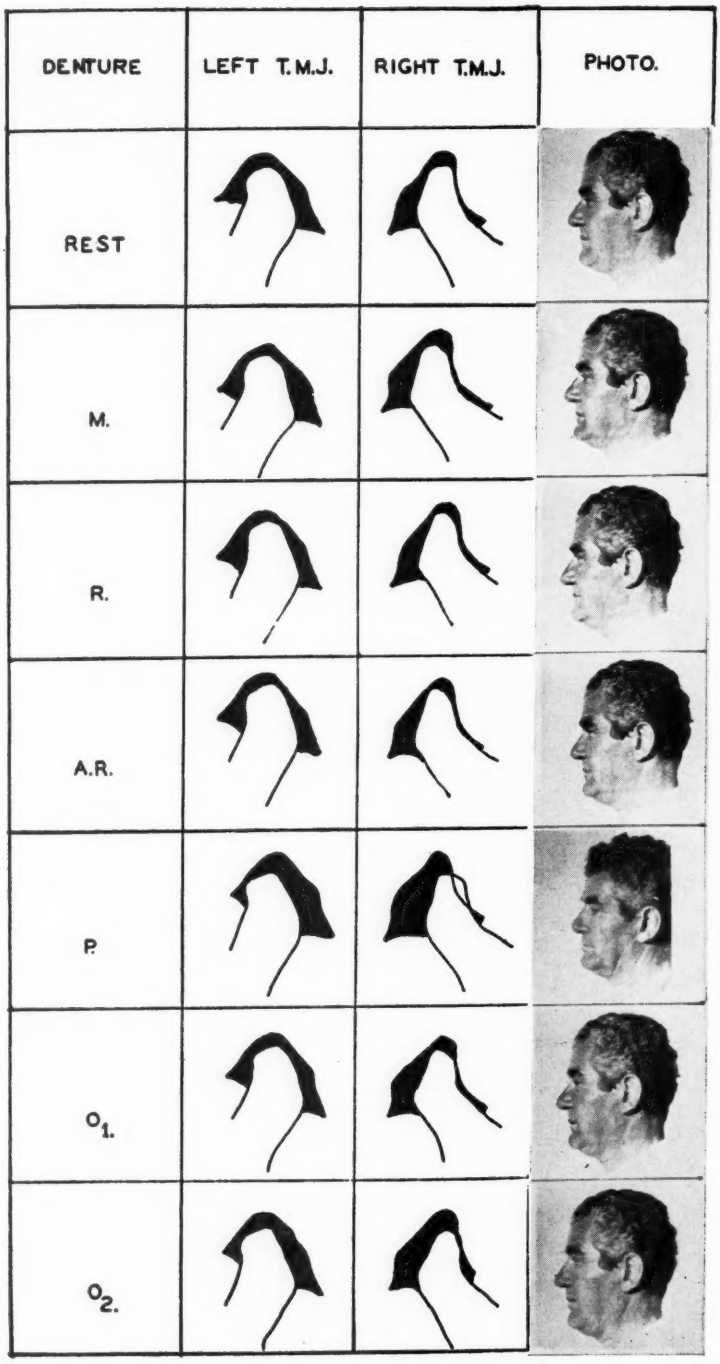

Fig. 6.—A comparison of the temporomandibular joint relations and the profiles with each of the six denture positions.

TABLE II.

DENTURE	PAIN	MASTICATORY EXPERIENCE	OTHER OBSERVATIONS
M. (muscular)	Very slight pain over ridge of left side after one week; prematurities were found to be causal, and after their elimination the dentures "felt fine"	Easy and effective; masticated well from the time of insertion; enjoyed steak 2 hours after insertion	Felt little difficulty or strangeness on insertion
Open I (opened to rest vertical dimension)	Some pain over ridge after first week, but not severe enough to necessitate removal of dentures	Easy and effective; period of adaptation very short	Not aware of opening; noted loss of retentive quality of upper; patient complained of not being able to bite hard
A.R. (artificially retruded)	Nothing unusual at time of placing; pain developed in third week; telephone conversation with patient, "This hurts me near the right ear"	"Have to chew forward to hit the teeth right"; (forward here probably relates to the maxillae and the statement thus indicates mandibular retrusive effort)	Pressure in front of right ear on biting hard at the time of placing denture
P. (protruded)	Pain started 3 days after insertion becoming very intense; two types of pain were noted—(1) dull pain over the joint area, and (2) much more severe pain over the right mandibular ridge; most severe over mylohyoid ridge where inflammation was marked; pain extended back from here into the throat	Pain necessitated removal of dentures at meals on many occasions	On insertion was aware that "jaw seems forward, but feels okay in a certain place"; noted decrease in retentive quality of upper denture after wearing this lower; pain in right mylohyoid area on biting hard
Open II (opened beyond rest vertical dimension)	Constant pain developing shortly after insertion of the dentures and localized on the right and left side of the ridge under the lower denture; pain increased in intensity when eating	Lack of masticatory power noted; pain after 4 days necessitated removal of dentures; this pain was in the medial pterygoid area; "It seems like a pressure relief when dentures are taken out—to explain this pressure would be difficult"	Now aware of the propped open position of the mandible; son had told him that his face looked funny with this denture in place
R. (retruded)	No pain	No problem in chewing	After 3 weeks of wearing the O_2 denture, the R denture was placed; "jaws feel more natural, big difference from that one"; (here the patient was referring to O_2 denture)

2 weeks; records were taken immediately after insertion, after 1 week's wear, and after 2 weeks' wear. In two instances, the patient was unable to attend at the appointed time; the dentures on these occasions were worn for a 3-week period to obtain the necessary number of records.

THE RESULTS

Three classes of results were obtained: (1) comments of the patient, (2) chewing observations, and (3) electromyographic records.

Comments Of The Patient.—These were obtained with particular regard to pain and eating experience, were tape-recorded, and are partially tabulated in Table II. The dentures are listed in the order of their insertion.

The upper denture was rebased as necessary to maintain a high order of retentive force. It is probable that different symptoms and experiences would have been described by the patient had the dentures been lacking in stability or retention.

Chewing Observations.—In order that a comparison might be made between the masticatory pattern of the edentulous patient and that typically seen in the adult with a normal occlusion, the writers observed five adults, with good dentitions, chewing carrots. The observations were made in the premolar area, since molar observations necessitated a displacement of the cheek with a retractor and permitted the egress of comminuted food into the vestibular sulcus, an eventuality which necessitated excessive volitional tongue movements. It is recognized that these observations are subjective rather than objective in nature, but their inclusion is seemingly justified on the basis of their being similarly noted by independent observers.

During incision, a protusion of the mandible was noted. A twisting action of the hand was used to effect the final cleavage of the bolus after the incisal edges of the teeth had made the initial penetration. The bolus was then moved into the molar area, and the initial comminution was effected by the mandible closing from a laterally displaced position. Contact (or a position very close to contact) of the teeth on the working side was distal and lateral to the median occlusal position, and thereafter, there was a slide into the position of maximal cuspal interdigitation.[9,10] After five to ten chewing strokes of this nature, smaller pieces of the comminuted carrot were seen to be displaced forward to the premolar area. At this stage, the masticatory strokes became more frequent, and their direction changed. Less lateral displacement was evident, and the mandible now moved directly into the intercuspal position without the primary contact (or near contact) posteriorly.

When softened chewing gum was substituted for carrot, the masticatory pattern immediately resembled the last stage of the cycle observed in the case of the carrot, and was carried out in the premolar area.

When the denture patient was observed chewing a carrot with the muscular position lower denture in place, a similar series of movements was noted to that described above. However, when the retruded and artificially retruded dentures were substituted, the forward slide of the mandible was not observed in the first stages of comminution. It was also observed in these cases that the midline devi-

ation viewed from the anterior was slightly less than with the muscular denture. When the protrusive denture was examined with the ridge in a painful state, the carrot initially was more anteriorly placed in the mouth, and a guarded and less powerful, more vertical, masticatory stroke was used to break down the bolus.

The placement of the first open denture (O_1) resulted in very little change in the vertical and horizontal components of the masticatory strokes from that seen in the muscular denture (M). The horizontal, midline shift was less than that seen in the M denture, but the initial forward slide was still noted. As would be expected, the vertical strokes were shorter and more mechanical in appearance than those exhibited with the M denture, since the O_1 denture had a vertical position equal to the rest vertical dimension of the patient.

The masticatory function of the second open (O_2) denture was, in appearance, the least suitable to the patient. The midline shift was minimal as was the vertical closing stroke. Here again, as in the O_1 denture, the masticating movements appeared very mechanical as if under volitional control. This was apparent in the patient's facial expression which seemed to be one of mental concentration.

The protrusive (P) denture presented a marked forward slide of the mandible with a lateral shift nearly equal to that seen in the M denture. Apparent effort by the patient was not as great as seen with the O_2 denture.

Observations of the chewing pattern with Tootsie Roll, a caramel-like candy, and carding wax were also made. In the former case, the pattern resembled that for the carrot, but the number of strokes with the mandible in a retruded position were fewer. With carding wax, only more direct strokes were observed.

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THE NATURE AND BEHAVIOR OF DENTURE CLEANSERS

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THE INCREASE IN THE number of dentures in service has stimulated interest in controlling the deposits and stains which normally collect on them. Fortunately, the modern denture has a smoother surface texture and is less permeable than vulcanite and, as a result, is somewhat easier to keep clean. However, the use of teeth with more natural contours and the trend toward stippled surfaces tend to provide more recessed areas for the accumulation of stains and debris and, consequently, increase the patients' cleaning problems.

This study of denture cleansers was undertaken in an attempt to evaluate the popular cleaning methods and to develop, if possible, a simple means of cleaning dentures with materials readily available to the patient.

THE SURVEY

Denture patients apparently use a number of cleaning materials in addition to the commercial cleansers currently available.[1] In order to study these materials, a questionnaire was prepared and sent to a number of patients of the denture department of the University of Michigan School of Dentistry. The questionnaire requested information regarding the type of cleanser employed, the method and frequency of use, the degree of satisfaction, and suggestions for improvements.

The tabulation of the 120 replies was complicated by the wide variety of cleansers reported, as well as combinations of materials and methods. The graphs which follow show the results for the subjects of greatest interest.

The preferences for cleaning materials are shown in Fig. 1. Even though 41 per cent of this group of patients use the commercial denture cleansers primarily, nearly one-half find it necessary to immerse their dentures occasionally in a household cleanser such as vinegar, or to use a brush with an abrasive material such as a dentifrice. The more popular home cleansers are listed on the graph in order of preference. Approximately one-half of the 18 per cent who use dentifrices primarily and the 11 per cent who use home cleansers also combine this cleaning with another method or material.

It is evident that despite claims made by the manufacturers of the commercial cleansers that immersion is all that is necessary for adequate cleaning, only 5 per cent use this method exclusively (Fig. 2). Both brushing and immersion are apparently considered desirable by most patients.

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In Fig. 3, the frequency of denture cleaning is shown. Brushing seems to be preferred after meals, possibly because of greater convenience, whereas immersion is more popular on a daily basis.

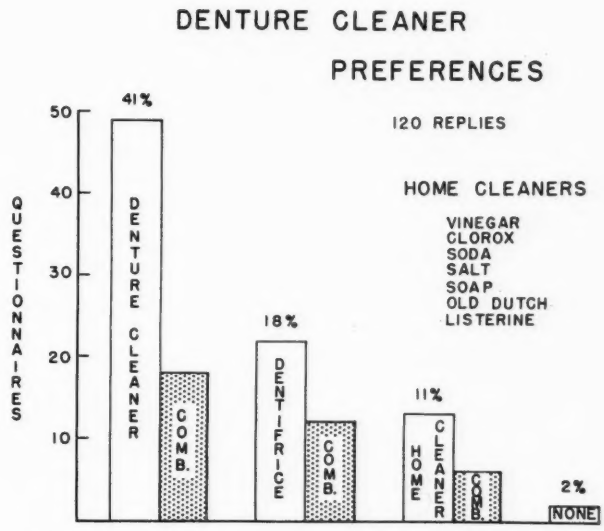


Fig. 1.—Comparison of denture cleansing materials used alone and in combination with other materials by 120 denture patients.

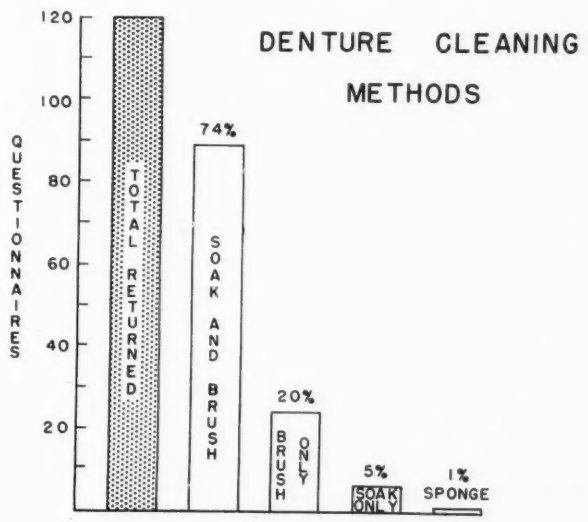


Fig. 2.—Methods of denture cleansing.

A majority of these patients are generally satisfied with their particular cleaning method (Fig. 4). Approximately one-fourth of those using the commercial cleansers and one-third of those using dentifrices or home cleansers would prefer something better.

There were a relatively greater number of suggestions for improvements in the commercial cleansers (Fig. 5). In view of their advertisers' claims, perhaps more is expected of them.

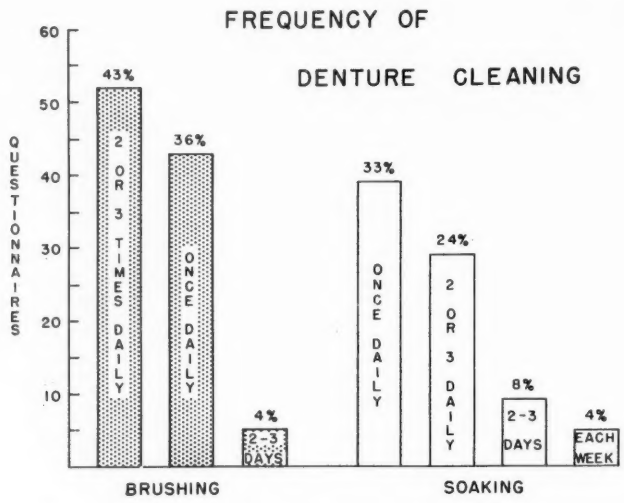


Fig. 3.—Frequency of denture cleansing by brushing and immersion.

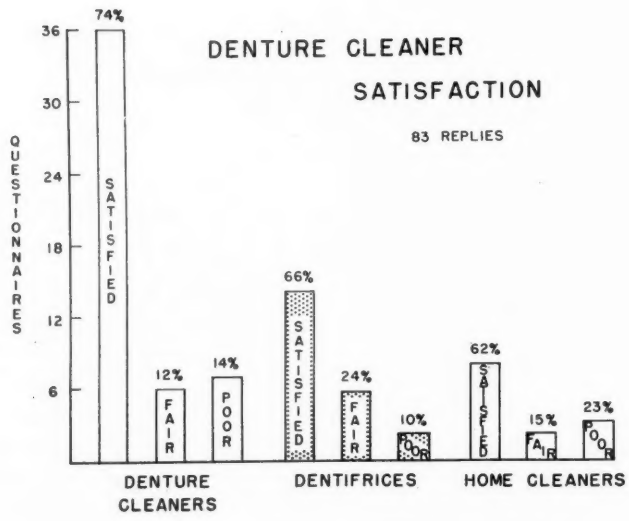


Fig. 4.—Degrees of satisfaction expressed for various denture cleansing materials.

EFFECTS ON DENTURE PLASTICS

Many of the household cleansers contain materials which are generally considered to be harmful to denture plastics or their coloring.[2] This portion of the

investigation was made to show the influence of these household cleansers on the denture bases, as well as the effects of an extended exposure to the commercial cleansers.

A series of flat specimens, 2 by 3 inches, of three different denture plastics were processed and finished in the usual manner. A small hole was drilled near the end of each sample so that it could be suspended by a stainless steel wire from the edge of a beaker and the lower half of the plastic immersed in a cleansing solution. Two specimens of each brand were exposed by this method for a period of three weeks in solutions of full strength Lysol, Listerine, rubbing alcohol, vinegar, Clorox, household ammonia, and Taxi. Saturated solutions of the following powders were tested: Vince, Polident, Dentur-Kleen, D.O.C., Kleenite, Caroid, Ora, Coleo, Dentglo, Stera-Kleen, Neutrox, Nyko, table salt, and baking soda.

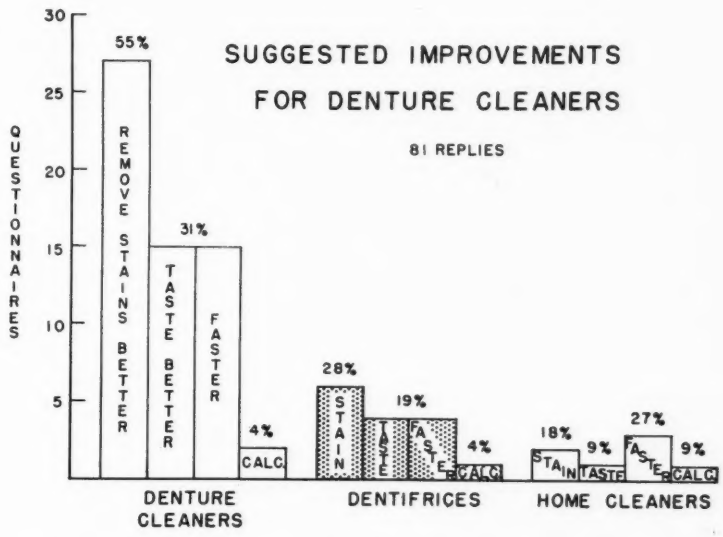


Fig. 5.—Improvements suggested by patients for various denture cleansing materials.

At the end of the test period, each pair of specimens was examined for changes. Lysol produced a darkening and softening of the lower portion of the plastic specimens, and Listerine caused a slight discoloration and moderate softening. Alcohol produced moderate crazing above the line of immersion on specimens of one brand of plastic, which is presumed not to be cross-linked. There were no obvious changes from any of the other solutions.

In order to magnify any alteration in color which may have occurred, one of each pair of specimens was irradiated for 24 hours by an ultraviolet lamp in a procedure similar to the American Dental Association color stability test. The changes previously mentioned in the specimens exposed to Listerine and Lysol were accentuated by further darkening. Color changes in all of the remaining irradiated specimens were within allowable limits when compared to those not irradiated.

From the results of these tests, it may be concluded that the commercial immersion denture cleansers are relatively harmless to denture plastics. The household cleansers such as Clorox, baking soda, ammonia, vinegar, and salt also appear to be harmless. However, substances which contain appreciable quantities of alcohol or essential oils cannot be recommended as denture cleansers.

EVALUATION OF THE COMMERCIAL CLEANSERS

Widely varying degrees of satisfaction with the commercial cleansers are reported by denture patients. The purpose of this portion of the study was to determine the active ingredients of these compounds, their mode of action, and to find means of evaluating their efficiency.

The immersion cleansers are sold in powder form and generally consist of alkaline compounds, synthetic detergents, detergent auxiliaries, and flavoring oils. With the possible exception of one commercial cleanser, they all seem to contain one detergent auxiliary in common, sodium perborate. This perborate is combined with an alkaline substance, such as a phosphate, and when dissolved in water becomes, in effect, an alkaline solution of hydrogen peroxide.

Upon contact with certain substances, such as the food debris and mucin on a denture, the peroxide decomposes and produces small bubbles of oxygen which tend to exert a mechanical loosening action between the denture surface and the foreign material. The amount of available oxygen should, therefore, determine to some extent the effectiveness of a cleaning solution. The percentage of available oxygen in a number of popular denture cleansers was determined and is given in Table I.

TABLE I. THE AVAILABLE OXYGEN IN COMMERCIAL DENTURE CLEANSERS DETERMINED BY ANALYSIS

1.	Vince	5.9%
2.	Neutrox	4.4%
3.	D.O.C.	4.0%
4.	Kleenite	2.7%
5.	Coleo	2.3%
6.	Nyko	1.7%
7.	Dentglo	1.4%
8.	Polident	1.2%
9.	Stera-Kleen	1.0%
10.	Ora	0.9%

The alkaline substances most frequently employed in denture cleansers are the phosphates, carbonates, and silicates. Only the caustic alkalinity, or that alkali over a pH of 8.5, is considered available for cleansing purposes. Chemically, it is probable that the hydroxyl ions furnished by these alkalies are attracted to the surface being cleaned and neutralize the electrostatic forces between the surface and the foreign material. This allows the debris to become detached and migrate into the bulk of the solution.[3] The penetration of these ions is aided by the wetting action of a surface-active material, and consequently, nearly all denture cleansers contain a small quantity of a synthetic detergent. The alkalies

also exert some chemical action on fatty and protein debris by saponification and hydrolysis.

The amount, then, of caustic alkali in a denture cleanser should also determine to some extent its effectiveness. The pH and the percentage of caustic alkali for a group of denture cleansers are shown in Table II.

TABLE II. THE pH AND PERCENTAGE OF AVAILABLE ALKALI ABOVE A pH OF 8.5 FOR COMMERCIAL DENTURE CLEANSERS

	pH	% CAUSTIC
1. D.O.C.	11.0	18.5
2. Polident	10.5	16.8
3. Nyko	10.4	15.4
4. Kleenite	11.2	14.0
5. Coleo	10.5	12.3
6. Stera-Kleen	10.5	9.8
7. Ora	10.9	9.8
8. Neutrox	8.5	——
9. Vince	8.5	——

An analysis of the cost per unit, or recommended dosage, is given in Table III.

TABLE III. COST PER UNIT DOSAGE FOR COMMERCIAL DENTURE CLEANSERS

	CENTS
1. Dentglo	0.54
2. Ora	0.69
3. D.O.C.	0.70
4. Stera-Kleen	0.85
5. Polident	1.30
6. Dentur-Kleen	2.00
7. Vince	2.10
8. Neutrox	2.80
9. Kleenite	2.30
10. Nyko	2.70
11. Coleo	4.80

The preceding tables may be compared more readily by arranging them side by side, with the cleansers possessing the more desirable properties, as before, placed toward the head of each column.

Although the chemical composition cannot be integrated with the cost, it is evident that those products which tend toward the head of all three columns would be preferred, with the final choice depending upon the properties which were considered most important.

Actual cleaning tests on dentures with accumulated stains and calculus deposits would seem to be a logical means of evaluating these cleansers. However, none was able to remove an appreciable amount of heavy deposits from

TABLE IV. COMPARISON OF SELECTED PROPERTIES OF COMMERCIAL DENTURE CLEANSERS

OXYGEN	CAUSTIC ALKALI	COST
1. Vince	D.O.C.	Ora
2. Neutrox	Polident	D.O.C.
3. D.O.C.	Nyko	Stera-Kleen
4. Kleenite	Kleenite	Polident
5. Coleo	Coleo	Vince
6. Nyko	Stera-Kleen	Neutrox
7. Polident	Ora	Kleenite
8. Stera-Kleen	Neutrox	Nyko
9. Ora	Vince	Coleo

dentures in two separate overnight immersions. Variations in the surface, contour, and the deposits on the dentures would make this method of comparison questionable.

On the basis of immersion tests, it may be concluded that these commercial cleansers can be recommended only for the removal of mucin deposited on the denture from the saliva and loosely held food debris. While their daily use may help to prevent the accumulation of heavy stains and calculus, once these deposits have been formed, some other method is required for their removal.

DENTURE BRUSHES AND ABRASIVE CLEANSERS

Nearly all suggestions given to denture patients regarding denture care include the use of a brush and a suitable cleaning compound.[4,5] This portion of the investigation was made to learn the effects of brushing and the commonly used cleansers on the surface of polished denture plastics.

A series of flat plastic specimens, 1½ by 3 inches, were processed and polished in the usual manner. One-half of each specimen was covered with masking tape, and the remaining portion was hand scrubbed for a period of five minutes with various brushes and cleansers used in cleaning dentures.

The initial tests were made with the brushes and soap and water. The brushes tested included a nylon hand brush, both hard natural and soft texture nylon tooth brushes, and eight commercial denture brushes.

In spite of the relative softness of nylon filaments in comparison to methyl methacrylate, there was definite scratching of the polished plastic surface by each nylon brush, as well as by the natural bristle tooth brush. Since nylon is manufactured by only one company, the small differences in scratching may be attributed to the variations in the diameter and length of the filaments.

The combination of a brush and an abrasive cleanser increases the degree of abrasion, as might be expected. Brushing with Bon Ami and Old Dutch Cleanser produced heavy scratching. Somewhat less scratching was observed with the dentifrices and the commercial denture cleansers.

The effects of the cleansers alone were determined by rubbing a plastic specimen for a period of five minutes with a cleanser incorporated in a moistened cotton roll. The abrasive household cleansers produced the heaviest abrasion, with the dentifrices and commercial denture cleansers scratching to a lesser extent.

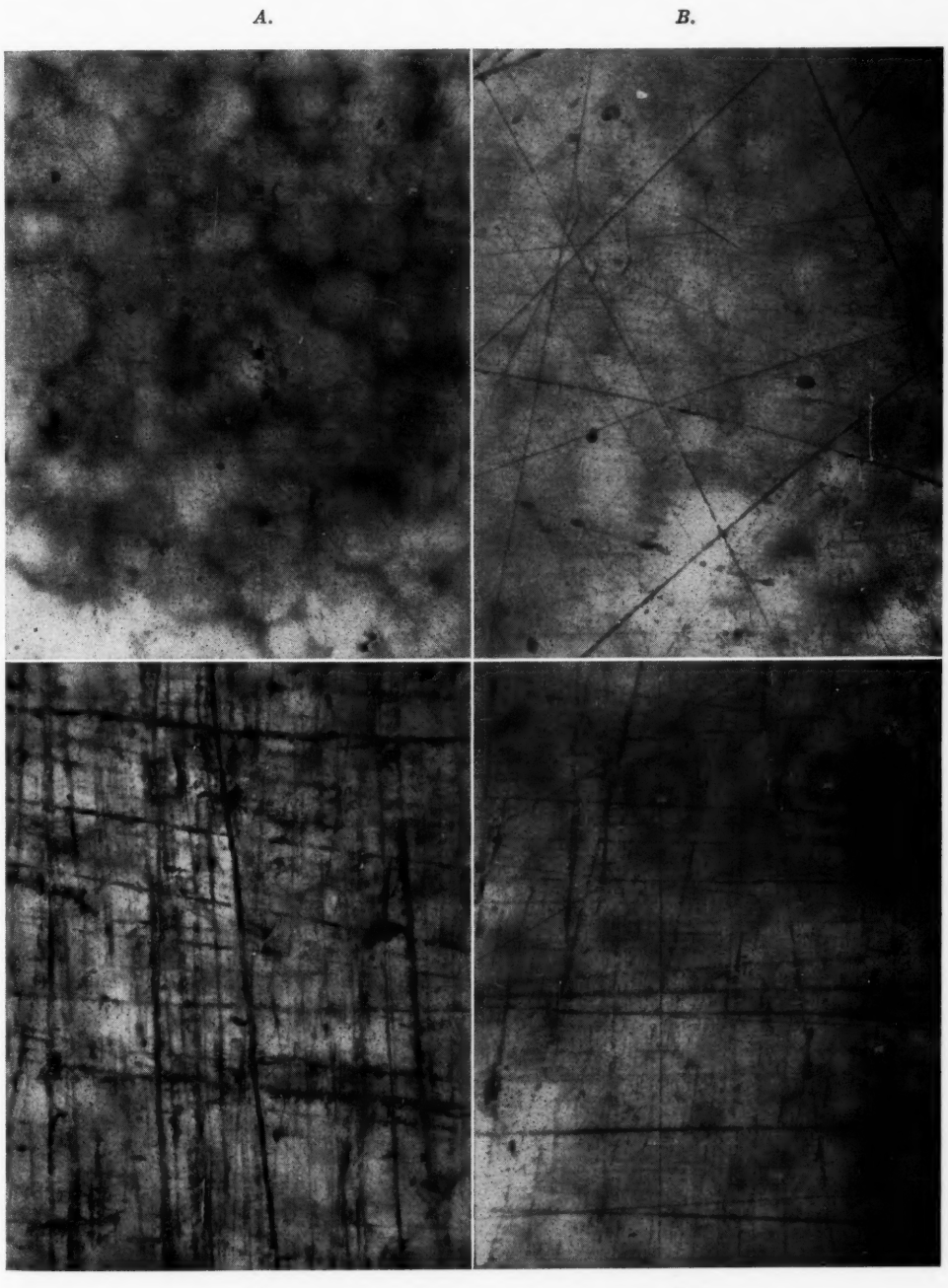
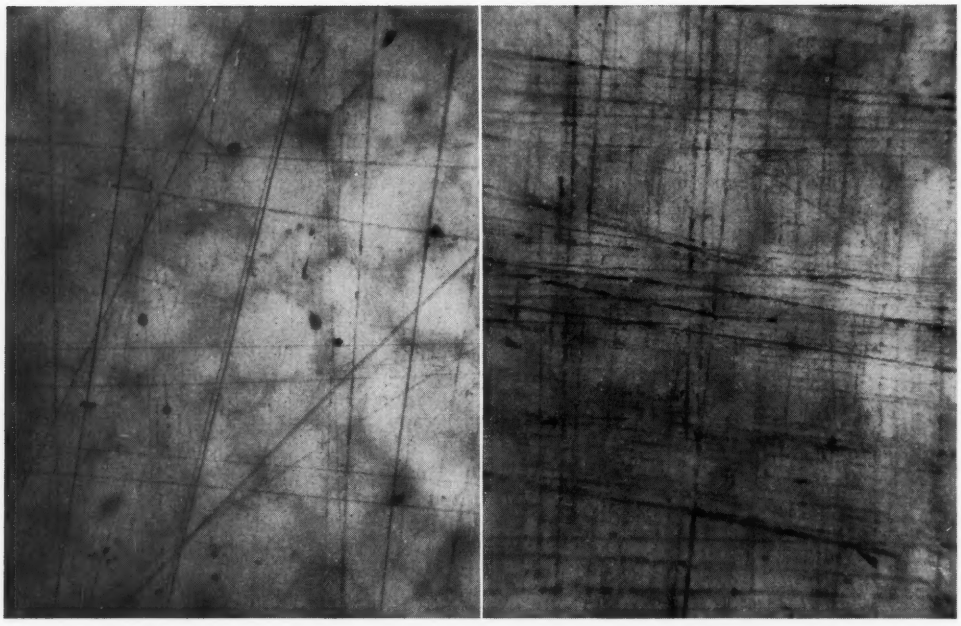


Fig. 6.—The abrasive effects on polished denture plastic. *A*, A polished plastic specimen, cleaned with *B*, a denture brush, cleaned with *C*, a denture brush plus Bon Ami, cleaned with *D*, Bon Ami plus cotton roll.



A. *B.*

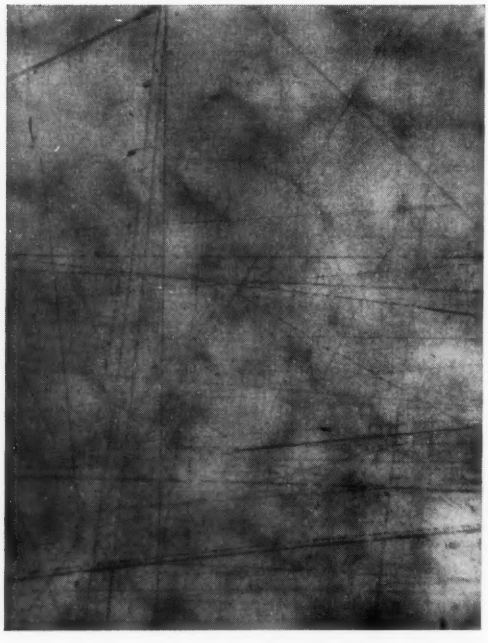


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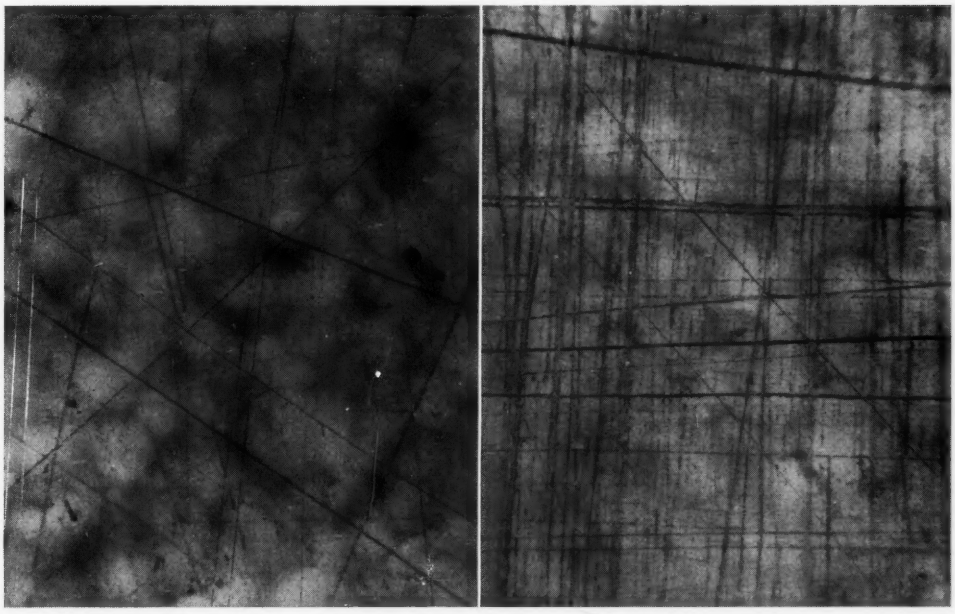
Fig. 7.—The abrasive effects on polished denture plastic of *A*, a denture brush, *B*, a denture brush plus a denture cleanser, *C*, a denture cleanser plus a cotton roll.



A. *B.*

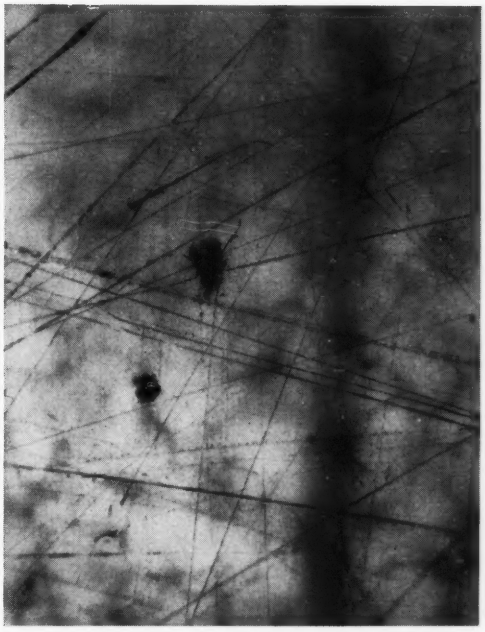


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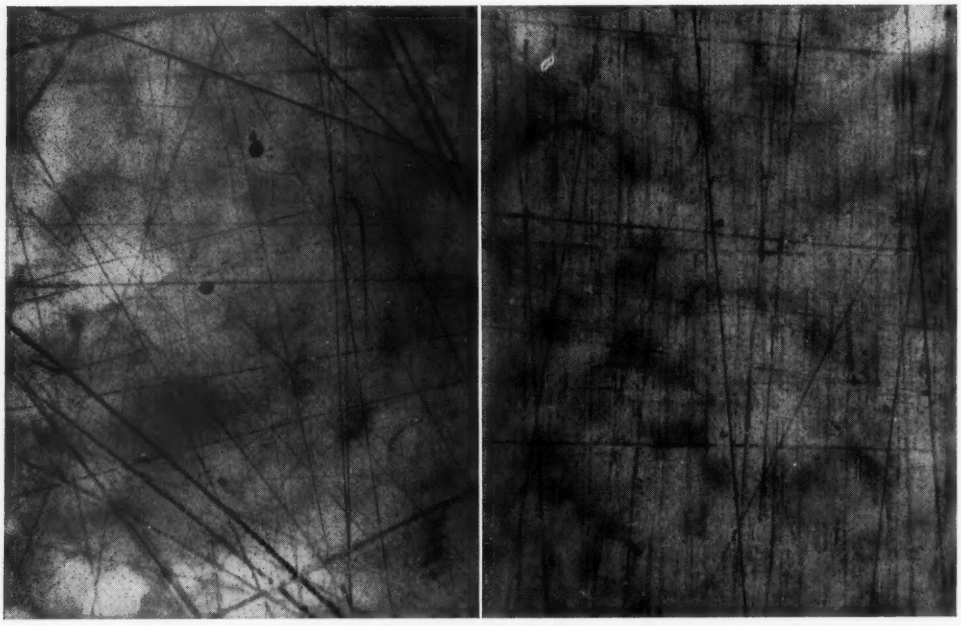
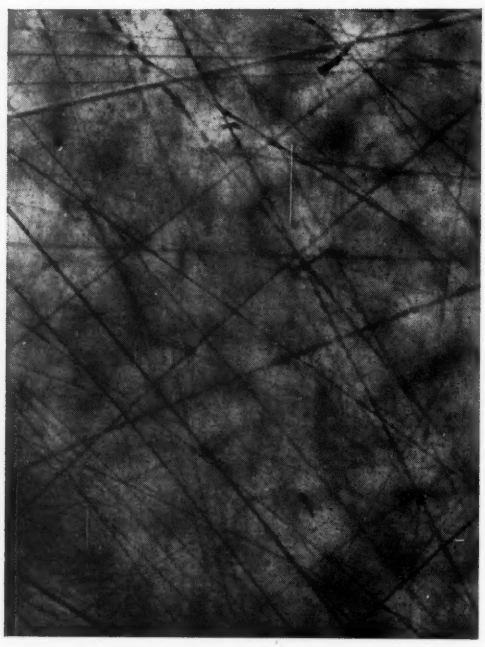
Fig. 8.—The abrasive effects on polished denture plastic of *A*, a hard natural bristle tooth brush, *B*, a tooth brush plus tooth paste, *C*, a tooth paste plus a cotton roll.



A. *B.*



C.

Fig. 9.—The abrasive effects on polished denture plastic of *A*, A soft-textured tooth brush, *B*, A tooth brush plus tooth paste, *C*, A tooth paste plus a cotton roll.

A series of photomicrographs (150×) of the surface of the plastic specimens used in these abrasion tests was made. The scratches were disclosed by lightly rubbing a film of colloidal graphite over the surfaces of the plastic. The first three illustrations (Fig. 6) show the effects of a typical denture brush, the results of brushing with the denture brush plus Bon Ami, and the abrasion caused by Bon Ami alone. The next group (Fig. 7) shows the effects of another denture brush, the brush plus a commercial paste denture cleanser, and the cleanser alone. The third group (Fig. 8) depicts the abrasive action of a hard natural bristle tooth brush, the tooth brush plus tooth paste, and by the tooth paste alone. The fourth group (Fig. 9) shows the results of brushing with a soft texture tooth brush, the brush in combination with tooth paste, and the effects of the tooth paste alone.

In brushing tests on dentures with heavy staining, the commercial cleansers proved to be quite effective. Stains were removed after a relatively brief brushing period. The dentifrices were also effective, although a somewhat longer brushing time was required.

Rapid cleaning is the major advantage in the use of a brush and an abrasive cleanser.[6] However, this advantage is likely to be outweighed by the disadvantages of loss of polish, the inability to reach into remote areas of the denture, and the increased possibility of dropping or damaging the denture while it is being scrubbed. It is apparent that any method which proves efficient in cleaning dentures that does not involve the use of a brush or abrasives is to be preferred.

A CHLORINE-PHOSPHATE CLEANSER

According to a series of immersion tests, the commercial immersion type denture cleansers are relatively ineffective in the removal of accumulated stains and calculus from dentures. One of the purposes of this investigation was to develop, if possible, an efficient and safe means of removing these deposits.

Dentures with heavy calculus deposits were immersed in solutions of various materials possessing properties which might prove useful for cleaning purposes. Pectic and protease enzymes proved to be slow in action and relatively ineffective in the removal of either calculus or stains. A number of the versenes, which are well known as chelating agents, were equally ineffective. Among the various home cleansers tested for their cleaning ability, such as vinegar, soda, and detergents, none gave encouraging results with the exception of Clorox. This solution appeared to be particularly effective in removing tobacco and food stains.

Chlorine solutions have been used to clean prosthetic appliances for many years,[7] but have lost favor in the United States because of their corrosive effects upon certain metals. A frequent result was the destruction of the pins used for the retention of anterior porcelain teeth. Severe color changes in the early plastic dentures were also attributed to the chlorine denture cleansers marketed at that time.

Since the modern denture plastics and their coloring seem to be resistant to even concentrated chlorine solutions and since there have been notable improvements in the manufacture of porcelain teeth, it was thought that the excellent cleaning properties of chlorine might be utilized again as a denture cleanser.

A small amount of solder is exposed at the base of the pins of porcelain teeth, and frequently a portion of the protective gold plating is removed during the fabrication of the denture. Since plastic cannot be depended upon to provide an effective seal, it became necessary to provide an anticorrosive material to protect these base metal parts.

Glassy substances, such as the sodium silicates, are frequently employed to protect metal surfaces from chemical corrosion.[8] These compounds are not always readily available and, in the case of water glass, form a disagreeable film on the dentures. However, one of the phosphates, Calgon, is known as a glassy phosphate and is available at any grocery store for use as a water softener. This phosphate seems to provide sufficient protection for metal parts to allow the use of hypochlorite solutions for cleaning dentures. In addition to this useful protective property, the phosphates are widely used in cleaning compounds for their calcium sequestering ability, wetting and emulsifying action, and metallic stain removal.

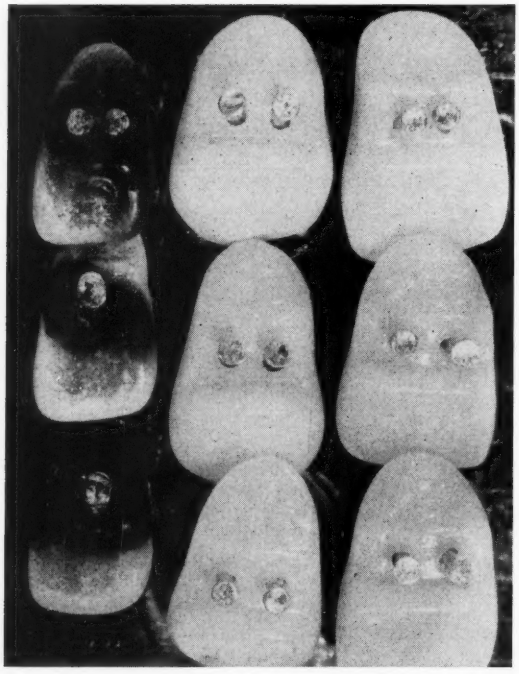


Fig. 10.—The effect of two days' immersion in Clorox and Clorox-Calgon cleansing solutions on the abraded pins of porcelain teeth. *A*, Blackened row at left, 1 teaspoon Clorox in one-half glass of water. *B*, Center row, 1 teaspoon Clorox plus 1 teaspoon Calgon. *C*, Right row, 1 teaspoon Clorox plus 2 teaspoons Calgon.

The anticorrosive properties of hypochlorite (Clorox) and Calgon mixtures were determined by exposing the base metal in the pins of a number of porcelain teeth by grinding and placing them in experimental solutions. Various amounts of Calgon were added to a series of hypochlorite solutions consisting of one teaspoon of Clorox in a half a glass of water. The results after two days are shown in Fig. 10. The blackened pins on the left resulted from exposure to a solution

of Clorox with no inhibitor, those in the center from a mixture of one teaspoon of Calgon added to the Clorox solution, and the pins on the right from a mixture with two teaspoons of Calgon added.

In addition to providing reasonably adequate protection for the pins of porcelain teeth, this final mixture of one teaspoon of Clorox and two teaspoons of Calgon is quite effective in removing stains and calculus from a denture. An average overnight immersion is sufficient to remove stains and all but the heaviest calculus deposits. Chlorine is well known for its bleaching and mucin solvent properties, and the addition of the phosphate apparently improves the penetrating and detaching action.

While this cleansing mixture is convenient and low in cost, it does not offer the pleasant odor and taste of the commercial cleansers. The mild chlorine odor is readily and completely removed from the denture, however, by rinsing in running water. The odor of chlorine does tend to linger on the fingers if they are placed in the solution.

It is doubtful if any hypochlorite is indicated for routine contact with the chrome-cobalt alloys[9] or with the base metals frequently used as retention loops in wrought wire partial dentures. However, darkening and the loss of the polish of these metals are not evident until after several days of exposure to this hypochlorite cleanser, and an occasional or accidental contact would not be likely to cause serious damage to them.

SUMMARY

1. The denture patients who showed enough interest to return a questionnaire spend considerable time and effort in attempting to keep their dentures clean.

2. Fewer than one-half of this group use the commercial denture cleansers. The remainder employ either dentifrices or home cleansers, such as vinegar, Clorox, soda, salt, soap, abrasive cleansers, or Listerine.

3. More efficient stain removal was the most frequently mentioned suggestion for an improved denture cleanser.

4. The commercial immersion denture cleansers appear to be harmless to denture plastics. Also harmless are the household cleansers, such as Clorox, baking soda, ammonia, vinegar, and salt.

5. Substances which contain appreciable quantities of alcohol or essential oils are not indicated as denture cleansers.

6. On the basis of immersion tests, the commercial immersion denture cleansers seem efficient only in the removal of mucin deposited from the saliva and loosely held food debris.

7. Since the commonly used brushes, abrasive cleansers, commercial denture pastes, and dentifrices all cause scratching of the denture, they cannot be recommended for routine denture care.

8. A cleaning solution consisting of 1 teaspoonful of Clorox, or similar hypochlorite, and 2 teaspoons of Calgon in a half a glass of water is an efficient and safe cleanser for an occasional overnight immersion.

9. This hypochlorite-Calgon cleanser is not indicated for routine use with any prosthetic appliance constructed with base metals.

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REMOVABLE PARTIAL DENTURES

OCCLUSAL AND PROSTHODONTIC TRAUMA

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TWO FUNDAMENTAL OBJECTIVES OF dental practice are the elimination or marked reduction of occlusal trauma and the preservation of the anatomic-physiologic status of the masticatory organ as a whole. When these objectives are applied to the removable partial denture field, it is recognized that the production of dental trauma is not limited to tooth occlusions, for other sources of trauma are present.

Trauma is defined as bodily injury produced by violent extrinsic agents such as force, thermal changes, chemical actions, and mental shock. These agents are factors having a variable bearing upon treatment success in removable partial denture prosthodontics.

Several authors in the field of periodontics have listed the most apparent causes of occlusal and prosthetic trauma. Several malrelated and malfunctioning non-occlusal conditions of the teeth and arches of partially edentulous patients contribute a trauma factor of no small concern to the prosthodontist. The problem in the field of removable partial dentures is not solely one of equilibrating the occlusion or of fabricating a prosthesis to merely plug a gap in the row of teeth, but rather it is that of rebuilding, as nearly as possible, the components of the masticatory organ to an ideal or to their original specifications. It seems logical to assume that the cause of dental trauma is basically related to the force whether associated with tooth occlusions or restorative appliances.

CAUSES OF MALOCCLUSION AND TRAUMA

The following causes of malocclusion and trauma have been cited by several authors: (1) cuspal interference, (2) malposition of teeth, (3) excessive vertical overlap, (4) excessive tooth mobility, (5) incorrect occlusal plane level, (6) incorrect interdigitation, (7) incorrect curves of Spee and/or compensating curves, (8) incorrect centric occlusion, (9) tooth abrasions associated with the loss of the vertical dimension of occlusion, (10) incorrect association of centric occlusion and centric relation, and (11) incorrect alignment, application, and design of clasp retainers, bars, and other denture elements.

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It seems profitable to focus the attention of dentists upon the mechanism by which traumatic force produces damage, the trauma production potential of the removable partial denture restoration, and the considerable traumatogenic conditions common to partially edentulous arches. Liberty will be taken, therefore, to treat lightly occlusal equilibration, per se, and to so slant this discussion that the above cited factors will be recognized and appreciated.

OCCLUSAL TRAUMA

Stillman[1] stated that occlusal trauma was a causal factor of periodontal disease. Subsequently, the investigations of Brekhus[2] indicated that periodontal disease was the greatest single cause of tooth loss, and Every[3] has projected recently that traumatic force is second only to decay as the greatest destroyer of oral tissues. Romine[4] projects that the removable partial denture is an appliance preventing trauma to teeth in arches where the continuity of the row of teeth is broken, and yet Glickman[5] and others[6,7] have charged this restoration as being a producer of trauma. Though the opinions differ in the ranking of occlusal trauma as the chief destroyer of tooth-supporting tissues and the creator of the need for a prosthesis, yet ample indications are present that great damage does occur to supporting elements from malocclusion and from poor engineering in restorations, especially the removable partial denture.

McLean[8] stated that early dentists were content to establish a centric (static) occlusion of the teeth and to presume that acceptable eccentric (dynamic) occlusions would automatically follow. These dentists noticed, after some years, that dentures were dislodged by the cusp tips and inclined planes of an interfering tooth or teeth in the eccentric ranges of occlusion. Thus, the term dynamic occlusion was coined to designate the gliding contacts (occlusions) of teeth in the excursions of the mandible.

The terms malocclusion and malarticulation designated, respectively, a faulty centric and eccentric occlusion of the teeth. The term bilateral balance designated a scheme of interarch contacts believed capable of stabilizing the dentures and the mandible during masticatory function. Bilateral balance became a standard required quality of occlusion in dentures and dentitions to equitably distribute occlusal stresses. Other terms were introduced, such as normal or ideal, typical or atypical, physiologic or pathologic, equilibrated-balanced, or traumatic-traumatogenic occlusions.

OCCLUSAL EQUILIBRATION

The term occlusal equilibration is a term designating a corrective procedure of abrasive reduction of cusp tips and cusp planes of natural teeth causing interfering and injurious contacts in centric (static) and eccentric (dynamic) occlusions. The procedures of correcting malocclusion of natural or artificial teeth are fairly parallel and have been amply discussed by clinicians of the past quarter century.

There are several methods of equilibrating occlusions, and these include: (1) selective spot grinding, e.g., Schuyler, Lauritzen, and Beyron; (2) muscle or force

balance, e.g., Sears, Ballard, and Blanchard; (3) initial contact, e.g., Coble, Hardy, and Denen; (4) oral abrasive paste milling, e.g., Black, Green, Brothers, and Jankelson; and (5) machine past milling, e.g., House, Stansbery, Terrell.

The materials and equipment used for these procedures are shown in Table I.

TABLE I. MATERIALS AND EQUIPMENT EMPLOYED IN OCCLUSAL EQUILIBRATION

MATERIAL	EQUIPMENT
Carbon paper—typewriter ribbon	Clay
Sheet wax	Central bearing point appliance
Fingernail lacquer	Mouth mirror
Mounted wheel and triangle stones	Handpiece and engine
Carborundum—pumice (powder and paste)	Massage vibrator
Mandrels and garnet disks	Adjustable articulator and attached milling device

The objectives of occlusal equilibration of natural dentitions[9] are: (1) to distribute the load of mastication to as many teeth as possible, (2) to deliver the forces of occlusion axially to the teeth, (3) to make the contacting areas spherical, or as a sphere against a flat surface, (4) to correlate the gliding eccentric and static centric occlusions, (5) to correlate the occlusions of restored occlusal surfaces with natural occlusal surfaces, and (6) to correlate occlusal surface width with root support value.

The objectives of occlusal equilibration of artificial dentures[10] are: (1) to eliminate prematurities and interferences in centric and eccentric occlusions, (2) to distribute equitably the contacts in the arch, (3) to unlock centric occlusion, (4) to harmonize occlusal anatomy with movement paths of the mandible, (5) to decrease occlusal surface area, (6) to establish adequate food trap and escape ways, (7) to re-establish the original vertical dimensions, (8) to create balance (centric, bilateral, or unilateral), (9) to simulate wear (for esthetics in anterior teeth), and (10) to eliminate or reduce to a minimum traumatogenic stresses associated with prosthetic appliances.

MECHANISM OF DAMAGE PRODUCTION

An early opinion of the mechanism by which occlusal trauma produces damage was: "The greatest percentage of periodontal disturbance . . . is caused . . . by improper lines of force produced upon the teeth during mastication or rest . . . the force directed along the lines of least resistance causes trauma; interference with capillary circulation causes lowered resistance in the traumatized area and infection takes place by way of the circulation."[11] Others believed that such a pathologic process in the periodontal membrane occurred only when an imbalance existed between the resistance ability of the periodontal structures and the occlusal stress.

Merritt[12] stated: "It is probably true in most instances that the loss of balance is due, not to the excessive occlusal strain, but to some condition of the periodontal tissues which robs them of their ability to withstand normal masticatory stress."

Fish[13] stated: "The periodontal attachment is destroyed by two agents, one toxic and one mechanical, and the dentist must consider both the toxic and the mechanical phases in treatment."

Gratzinger's[14] concept of "dynamic irritation" projects that trauma is produced by movements and inherent forces associated with restorations, such as removable partial dentures and clasp retainers, and thus may not be a direct resultant of occlusal force.

Moyers[15] projects that: A need exists to control the stress on teeth, for such force is immediately transmitted to periodontal membranes and by their fibers to the supporting alveolar bone and that such stress conditions modify the blood supply in the periodontal membrane which in turn stimulates regressive changes in the alveolar bone. Thus, a light continuous force creates a stasis in the blood supply and the ensuing pathologic changes permit tooth movement.

These pathologic changes are characteristic of hypo- and hyperfunction of the periodontal membrane and of the tooth. A force of 25 Gm. per square centimeter is sufficient to diminish this blood supply, and a tooth movement of 0.2 mm. is sufficient to create such a disruption in the blood supply. A continuous application of light force for several hours will overcome the resiliency of the periodontal membrane and initiate pathologic change.

PROSTHODONTIC TRAUMA

In removable partial denture prosthodontics, the dentist not only carries the responsibility for equilibration of the existing natural and fixed artificial tooth occlusions, but also for the elimination or reduction to a minimum of other physical and functional oral conditions which are host factors of prosthodontic trauma. Sources of trauma yielding "dynamic irritation" receive little attention during the designing step of removable partial dentures as it is routinely executed by the average general practitioner and the average laboratory technician.

It is doubtful if many dentists execute a diagnostic survey step to detect and evaluate the many oral physical factors involved in trauma production. Thus, faulty engineering in the design step becomes a fertile source of damaging stress and torques by the functioning prosthesis which bear directly upon the biomechanical failure of the appliance and the treatment rendered.

Glickman[16] has projected that visualization and consideration of all possible movements of the removable partial dentures must be given in the design step, for in such movements reside potential strain and torque on abutment teeth and other supporting and stabilizing tissues. Years ago, prosthodontists, such as Dittmars, Chappell, and Neurohr, projected essentially the same need, and it was termed Skolodontic movement or force. Thus, preparations of the oral structures for such a prosthesis must eliminate, in so far as possible, any undesirable static and functional torque and strain potentials in the occlusions, in the crown forms, and in the interaction of abutment teeth and appliances during function.

CONCEPTS OF PRACTICE

It is a "horse and buggy" approach not to accept the concepts that:

1. Certain teeth are expendable in order to gain an improved over-all result.

2. Most abutment teeth require corrective restorations and that the restoration of choice is the full veneer crown.

3. Unit casting of metal frames is the most satisfactory and economical fabricating method.

4. The incorporation of plastic denture bases for extension base partial dentures is the most satisfactory and economical way of caring for postinsertion ridge changes.

5. The use period value and the remedial-restorative health value of a removable partial prosthesis (frame) is basically equal to that of any other dental restoration.

6. The science, skill, and experience required in this field is equal to that required of any other field of dentistry.

7. The restorative, remedial, and therapeutic values of restorations depend to a large degree upon the patient's good health and proper upkeep care as well as upon the craftsmanship and the biologic and mechanical knowledge of the dentist to create, install, and maintain the restoration, be it a removable partial denture, a fixed partial denture, or an individual tooth restoration.

POTENTIALS OF PROSTHODONTIC TRAUMA

Prosthodontic trauma may be the result of one or more potentially damaging conditions:

The potential of Class I lever action of the prosthesis in function which is due primarily to the location of multiple edentulous areas in relation to the axis of rotation and, secondarily, to their relation to the most effective and habitual zones of comminuting function.

The potential of torque and wedging action which is caused by the oblique orientation of the axis of rotation for vertical plane movement resulting from unequal numbers of retained teeth in opposed arches or in the lateral halves of an arch.

The potential of overload on abutment teeth and residual ridges arising from deficient bone support, insufficient denture base coverage, or torque on abutment teeth.

The potential of anteroposterior slippage of retainers, braces, and denture bases on the working side which is due to the angular application of load forces associated with poor tooth-crown contours, ridge form, ridge interrelationship, and poor denture design and application.

The potential of rotatory slippage of the prosthesis in the horizontal plane, on the nonworking side about a point axis (single abutment tooth) which is due to: the angular application of load forces associated with medial (lateral return) movement of the mandible, the improper contours of crowns, and to the improper design and application of denture elements.

The potential of vertical plane slippage about an anteroposterior axis on the working side resulting from unfavorable location of the rests and the buccal cusps (denture teeth) to the ridge crest, or interalveolar stress plane, and/or a similar

vertical slippage of the prosthesis on the nonworking side. Both slippages are caused by poor crown form or design and application of denture elements.

The potential of gravitational pull on abutment teeth resulting from weightly extension type upper partial dentures, from poor design and application of denture elements, and from a lever advantage inherent in the number and distribution of remaining natural teeth.

The potential of divergent migration of abutment tooth or saddle resulting from faulty circumferential contour of the abutment tooth, improper or deficient fixation or application of retainer, improper or deficient reciprocal clasp action, and/or improper rest orientation.

The potential of tipping the abutment teeth resulting from improper reduction of mucosal resiliency, clasp arms too rigid, deficient saddle extension, or an improper impression technique.

TRAUMATOGENIC ORAL CONDITIONS

The following items are associated with case analysis and have a bearing on trauma produced by dynamic irritation from prosthesis and on occlusal trauma which produces the same and perhaps other damaging and destructive forces:

1. The symmetry and balance in numbers, position, and interarch relationship of the remaining teeth in each arch.
2. The inclination, rotation, extrusion, and intrusion of the teeth in each arch.
3. The carious, eroded, or abraded condition of the remaining teeth.
4. The condition of fillings and prosthetic restorations existing in the dental arches.
5. The gingival and periodontal condition, the bony support, and the mobility of the remaining teeth.
6. The interarch relationship of the remaining natural teeth to opposed edentulous areas.
7. The relationship of abutment teeth in an arch to the ridge crest of the edentulous areas of that same arch.
8. The correctness of the existing centric relation of the mandible, the centric occlusion and cusp interdigitation of teeth, and the association of centric relation and centric occlusion.
9. The bilateral correctness of the location, inclination, and curvatures of the occlusal plane.
10. The age, sex, social and economic status, and the mental attitude of the patient.

STRESS-BREAKERS

Many dentists consider stress-breaking a preferred manner of equalizing the resiliency of the mucosal and periodontal (soft tissues) or denture movements in function. Others consider that denture movement is essential to give stimulation to the soft tissue. Grubb[6] has stated that it is impossible to fix teeth so that they would not be stimulated. De Van[17] has analyzed stress and saddle movement and

considers such movement detrimental to tissue integrity. Wright[18] has reported that the mucosa in more than 60 per cent of complete denture patients becomes variably hyperplastic in one year's time, primarily due to denture base movement. Pendleton[19] has stated that denture movement is largely responsible for a low-grade inflammation in mucosal tissue which causes other undesirable tissue changes. Gardner[20] and Belding[21] have stated that denture movements are contraindicated from the point of view of preserving its supporting foundation and the extension of its service period.

I believe that stress-breakers contribute no beneficial value, but rather a detrimental value to oral tissues and to denture use, thus decreasing the useful life period of both. Reports on tissue thickness, resilience, and movement values seem to contraindicate their use. The displaceability of a complete denture base with normal mucosal tissue has been given by Boucher[22] as 0.08 mm. and 0.06 mm. though the mucosal thickness is 1.0 to 2 mm. Coolidge[23] states that the normal thickness of the periodontal membrane is 0.18 to 0.22 mm. which gives a 0.15 mm. buccal or lingual crown movement. Manly[24] has projected that the potential of buccolingual tooth movement is three times that of vertical plane movement. Surely such potential values of movement, strain, and stress do not indicate the need of a vertical plane stress-breaker appliance.

Mucosal thickness exceeding the normal range should be treated by surgical excision rather than by employing a mechanical appliance whose effectiveness immediately deteriorates from the day of insertion and initial use. All the motion or freedom desired in any normal case can be obtained by proper clasp form and application. It seems that Perry's[25] statement of 1905 is very apropos of this device: "We have outgrown the idea that the mouth is the proper place in which to make a display of artistic work solely to show what can be done. The security and comfort of the patient is of more importance than the legerdemain of the operator."

SUMMARY

There is a tendency among dentists to approach the problem of the removable partial denture treatment from the mechanic-artisan point of view, rather than from the biologic, health, and professional point of view. The trend is to differentiate these spheres of activity properly in prosthodontics and to place greater responsibility on the health operator—the dentist.

Many more items relating to occlusal trauma and "dynamic irritation" are associated with partial prosthodontic treatments than have been discussed in this essay. The hope is that dentists will become increasingly conscious of the need to eliminate these various traumas associated with this branch of prosthodontics and that much less resistance will be offered professionally to the considerable preparations generally needed by the oral components of a broken-down masticatory organ, such as is common to patients wearing removable partial dentures.

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FIXED PARTIAL DENTURES

INTERRELATIONSHIP BETWEEN RESTORATIVE DENTISTRY AND PERIODONTICS

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IT HAS BEEN STATED THAT successful restorative dentistry must have as its basis a healthy foundation (Figs. 1 and 2). Stated in another way, we may say that periodontal health is the basis of all restorative dentistry. The relation between restorative dentistry and periodontics is *interdependent.* Often we hear the concept that restorative dentistry is as good as its foundation, the periodontium. However, we should not overload the concept in reverse—restorative dentistry is also the basis of a healthy periodontal tissue (Fig. 3). Bryan[1] stated that, "We must keep constantly in mind that the dental restorations we make have a twofold purpose; the restoration of the tooth or teeth to function and the protection of the supporting tissues from injury." It is clear then that restorative procedures must be based on not only mechanical specifications but also must fulfill biologic requirement.

The preservation of the natural dentition should be the constant objective of dentistry—not its replacement. Nature never intended that we should lose our natural teeth any more than our other organs. Investigations of our aging population reveal that at the age of 70 years, 80 per cent of women and 70 per cent of men have lost all of their natural teeth. This situation is not inevitable. Preventive measures instituted earlier, while the prognosis is favorable, would considerably change the picture. A dental practice which stresses preventive objectives consists of two basic aspects, periodontics and restorative dentistry. The first, *periodontics,* is preventive and curative and involves maintenance of periodontal health (Fig. 2), and second, *restorative dentistry,* is the replacement of missing teeth and the hard tissues thereof. Romine[2] defines the restorative phase of dental practice as the individual restoration, the fixed and removable partial denture, and the splinting procedures. The individual restoration is regarded as the basic unit of all of the above restorative services. He further states that the individual restoration must be built to two sets of specifications; namely, periodontal and mechanical.

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The periodontal specifications (Fig. 4) of the restoration are determined by its outer surface. These specifications are concerned with contact, contour, occlusion, margins, and polish. These factors determine to a large extent the protection the supporting structures receive from the restoration. The cause of vast amounts of periodontal disease is directly related to the failure to meet periodontal specifications (Figs. 3, 5, 6, 11, and 12). The literature abounds in references to "faulty dentistry" as a prime local etiologic factor in the initiation and progres-

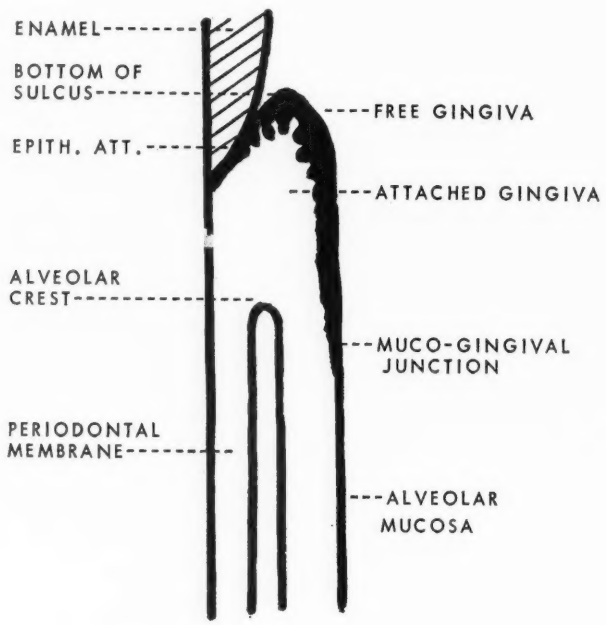


Fig. 1.—Diagrammatic relationship of normal periodontium (After Orban, B. J.: Oral Histology and Embryology, ed. 3, St. Louis, 1953, The C. V. Mosby Co., p. 223.)

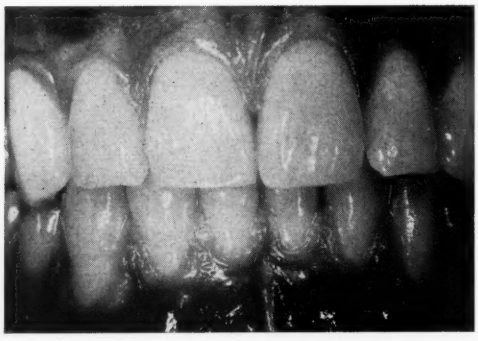


Fig. 2.—A healthy periodontium. Note the stippling and the marginal and papillary contour of the gingival tissues.

sion of periodontal disease. The prevalence of faulty dentistry as a prime local factor in the etiology of periodontal disease is substantiated by clinical observation. Many investigators feel that over 80 per cent of all periodontal disease is caused by local factors such as poor oral hygiene, calculus, and defective restorative dentistry (Fig. 6).

The mechanical specifications are determined by the inner surface of the restoration.[2] Laws underlying the basic requirements of cavity preparation were

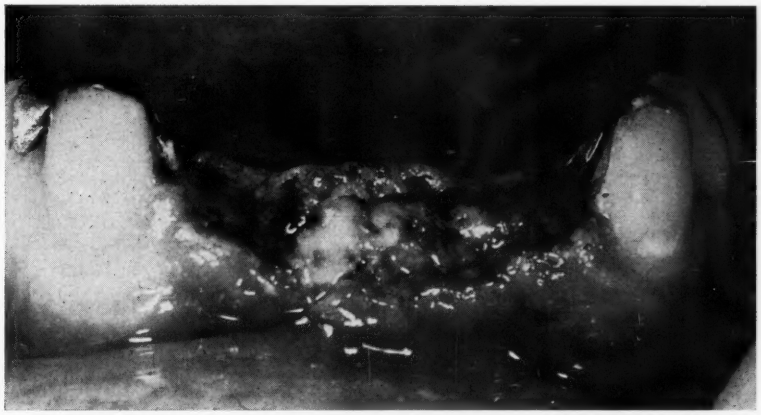


Fig. 3.—Acute necrotizing ulcerative gingivitis (fixed partial denture has been removed). The gingival impingement and irritation is due to improperly designed pontics. The most severe tissue damage is in the area of greatest pressure and local tissue injury.

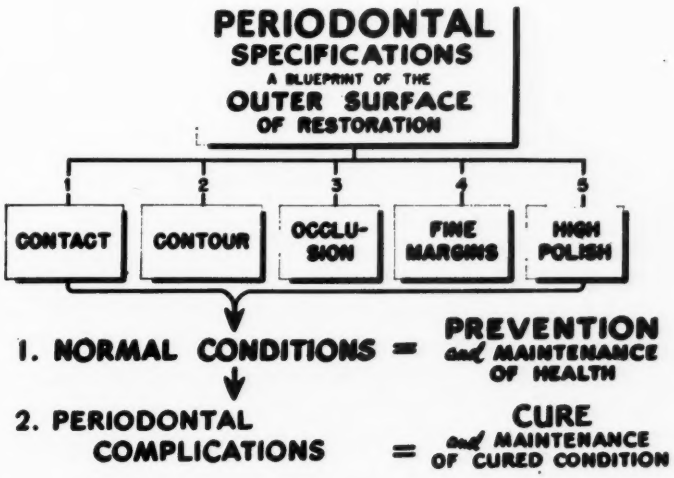
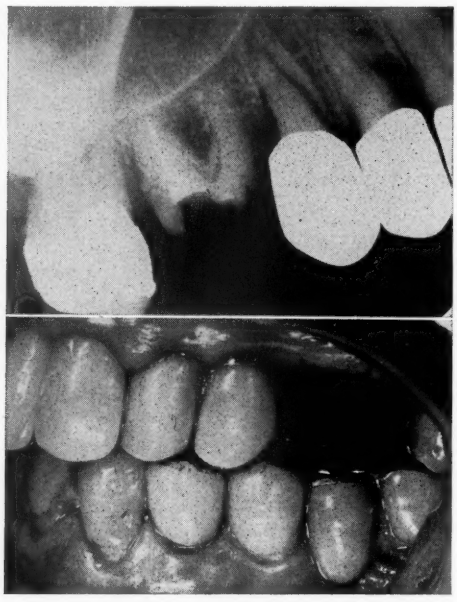


Fig. 4.—Periodontal specifications of restorations. (After Romine, E. R.:[2] J.A.D.A. 44:742-747, 1952.)

established years ago by Black.[4] Physical and mechanical principles in crown and bridge prosthesis have been advocated by Smyd,[5] Tylman,[6] Klaffenbach,[7] and others.[8]

A.



B.

Fig. 5.—*A,* A roentgenogram of upper posterior teeth. Note the overcontoured crowns, gingival overhanging margins, lack of proper interproximal embrasure, defective contact areas, and evidence of alveolar resorption and periodontal traumatism (widening of the periodontal space). *B,* A clinical view of the same teeth as in Fig. 5*A*. The teeth are in lateral "working" occlusion. Note the cuspal interference, gingival impingement, and enlargement of marginal and papillary areas. The upper second bicuspid was in a state of traumatism and showed evidence of excessive mobility. Note the lack of proper proximal contour of the restorations and the lack of interproximal embrasure space to accommodate the gingivae.

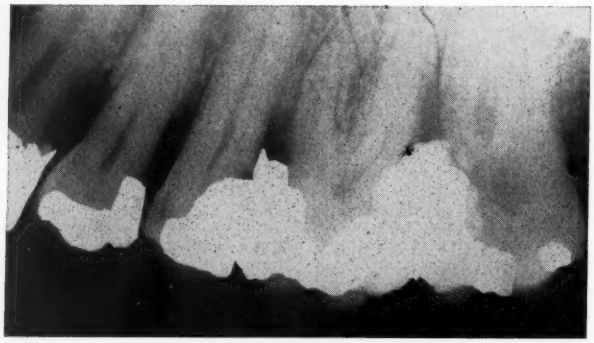


Fig. 6.—A roentgenogram of a patient's upper posterior teeth. Note the lack of proper contact and overhanging gingival margin of the restoration in the cuspid. Note the lack of distal contact of the upper first bicuspid. Note the overcontoured and overhanging proximal margins of the restorations in the molar teeth. This is evidence of violation of the periodontal specifications for restorative dentistry resulting in periodontal disease.

PERIODONTAL SPECIFICATIONS OF CONTACT AND CONTOUR

The continuous tooth-to-tooth contact relationship within the dental arches is mandatory if proximal periodontal health is to be maintained. This relation is to a large extent due to proper arch form, uninterrupted tooth-to-tooth proximity, alveolar support of the roots, and the transseptal periodontal membrane fibers. Perhaps more restorations fail with respect to proximal specifications than any other aspect of the restoration. The biologic phenomena, such as continuous interproximal wear approximating 1 cm. at the ages of 40 to 50, results in a flattening of the proximal surfaces. When constructing restorations for such teeth, proper proximal contour and contact areas should compensate for the loss of proximal tooth structure. According to Black,[9] "the proper contact area should be similar to the rounding of the surfaces of two marbles when placed in contact, continuing this rounding gingivally then this curve reflected to form a concavity, followed by a straight line toward the gingival results in a proximal form that will not impinge upon the gingival papillae."[9] This contact and proximal form is recommended for bicuspids and molars. Protection of gingival tissues from injury, such as food impaction, and retention is directly related to such periodontal specifications as contour, contact, margins, and polish of the restoration.

Fine margins of dental restorations, especially in the proximal areas, are mandatory in the prevention of periodontal pathology. Imperfections, such as overextension, underextension, rough or unpolished proximal surfaces, and margins, act as irritants that result in inflammation. Nature itself cannot cope with such a situation, since it cannot resolve such an irritant. The resulting inflammation is not a disease, but a highly important bodily reaction to an irritant which has as one of its aims the elimination or neutralization of the irritant followed by resolution and repair. To resolve this situation, we do not treat the inflammation but remove the irritant or environment that produces damage to the tissue so resolution and healing can occur. It has been stated[3] that about 80 per cent of all periodontal disease is caused predominately by local factors. Failure to achieve the periodontal specifications of restorative dentistry results in extensive periodontal disease. This can be substantiated by routine clinical observations.

PROSTHETIC CONSIDERATIONS

From the periodontal viewpoint, it is desirable that any missing tooth from second molar to second molar be replaced. Where indicated, the fixed partial denture is the method of choice. It fulfills the requirements of function and limitation of movement through a splinting effect, especially if periodontal disease has caused the loss of bone support. The fixed bridge is desirable when there is normal bone support and unchanged tooth position. However, properly designed stress divider (broken-stress) construction may also be utilized.[10] It has been stated that the fixed partial denture is contrary to individual physiologic tooth movement that would result in understimulation. (However, regardless of whether it is fixed or removable, complete or absolute fixation is impossible.) The more important problem is the avoidance of excessive movement.[11] As a general rule, replace-

ments should be made fixed completely or with broken-stress where possible, and removable appliances should be used only where it is impossible to construct a fixed partial denture. This is particularly important in those cases of weakened bony support due to the effect of periodontal disease. In such cases, the desirability of a splinting effect to negate excessive tooth movement is mandatory for biologic specifications. The fixed bridge gives an action of one tooth with multiple roots.

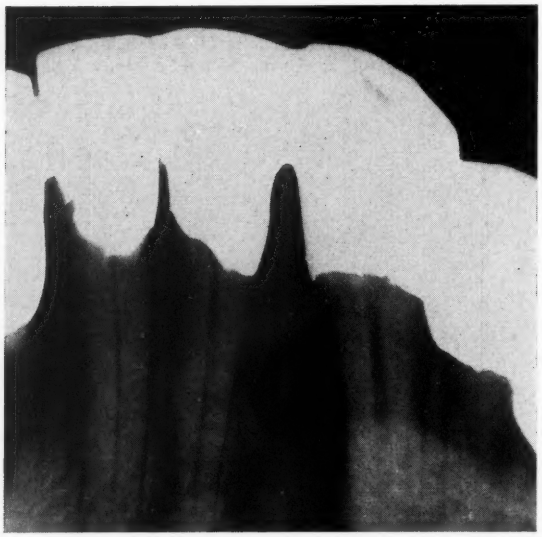
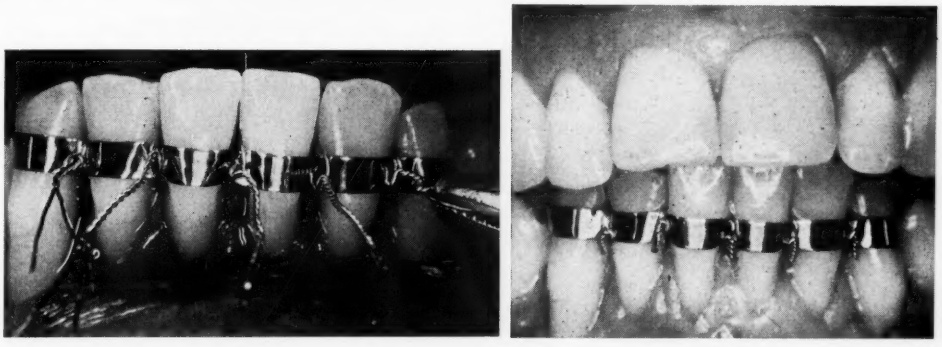


Fig. 7.—Permanent fixed periodontal splint. Utilization of three-quarter crowns and pinledged crowns soldered together as one means of efficiently splinting anterior teeth weakened as a result of periodontal disease. (Courtesy of M. G. Walls.)

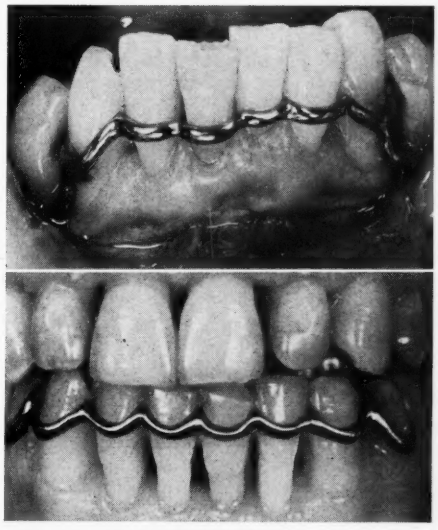
From the periodontal viewpoint, we do not splint enough in our restorative and periodontal procedures. The splinting together of two or more weakened teeth, either rigidly soldered together or attached by means of dovetail lock joints, serves to prevent excessive movement. These features may be utilized in designing a multiple fixed partial denture abutment. Other procedures utilized when weakened support is evident are: reduction in the size of the occlusal surfaces, occlusal adjustment of incline planes not only to prevent occlusal trauma and prematurities, but also to direct the forces of occlusion in a manner the supporting tissues are built to withstand most efficiently, i.e., in the direction of the long axes of the teeth. The splinting together of a weak tooth to a solid tooth by means of a solder joint connecting ¾ crowns or other castings, such as pinledge retainers, should be utilized when indicated (Fig. 7). Groups of teeth may be splinted together when they are individually weak (Figs. 8, 9). Collectively, they become solid and strong.[2] Continuous clasps in removable partial dentures can serve to meet the objective of splinting (Fig. 10). Poorly designed margins of castings and lack of embrasure space for gingival tissues cause chronic irritation and impingement that not only cause gingivitis but also hyperplasia of gingival tissue (Figs. 3 and 5). Improperly designed partial dentures may overload abutments, lack or have in-

Fig. 8.—A temporary periodontal splint. Soft stainless steel ligature wire 0.020 was utilized for stabilizing the upper anterior teeth after pocket eradication. The large cuspid-to-cuspid loop of soft stainless steel wire was secured by interdental ligation. The advantages of this method of splinting are simplicity of construction and ease of manipulation of materials.



A. *B.*

Fig. 9.—*A*, Temporary splinting of periodontally involved teeth. The splint was made from a large loop of stainless steel band material 0.100 x 0.003 passed around the lower anterior teeth. Interdental ligation is done with stainless steel ligature wire 0.011. Note the hemostat utilized in twisting the interdental ligatures. *B*, The completed temporary periodontal splint. Individual teeth which were formerly loose and weak now become solid and strong collectively.



A.

B.

Fig. 10.—*A*, A lower removable partial denture in place. Note the splinting effect of the continuous labial clasp. The patient's lower anterior teeth were treated successfully for periodontitis by pocket eradication and instructions in oral hygiene. *B*, Lower anterior teeth splinted by means of a removable splint. After periodontal therapy, the loose teeth were splinted to reduce excessive mobility. (Courtesy of B. J. Orban; Periodontal Disturbances: Practical Management, J.A.D.A. **35**:545-556, 1947.)

adequate occlusal rests, exert continuous clasp tension, and may also result in palatal impingement resulting in irritation and periodontal disease (Fig. 11). Goldman[12] stated that the local periodontal lesion is the sum result of *intensity* of the irritant, times the *frequency* of the irritant, times the *duration* of the irritant, modified and governed by the resistive and reparative factors of the individual. Inflammation and periodontal lesions that result from a defective margin of a casting are obvious. Inflammation in itself is not a disease, but it is nature's reaction to an irritant. With the elimination of the causative factors, inflammation usually subsides, and the tissues return to normal. If the etiologic factors are not removed,

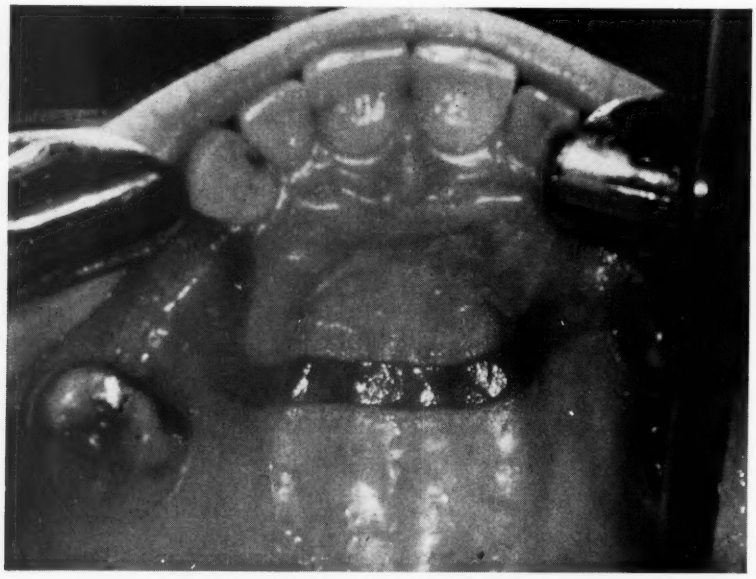


Fig. 11.—The result of a palatal and gingival impingement from an upper removable partial denture. Note the "imprint" of the partial denture base and the degree of gingival irritation. The tissue changes are hyperplasia of the epithelium and connective tissue and inflammation.

a chronic inflammation will develop in the periodontal tissues. According to Menkin,[13] the injured cells liberate necrosin, a material that causes necrosis of tissues and occlusion of the lymph vessels, thus inhibiting drainage of fluid from the area. The inflammatory reaction progresses from the gingivae to the alveolar crest, following the course of the blood vessels. This progressing inflammatory reaction is associated with alveolar crest resorption. The condition is referred to as periodontitis. With the loss of supporting tissues due to inflammatory or other periodontal diseases, secondary occlusal trauma may develop. The resolution of periodontal disease by therapy should precede major restorative procedures.

PREREQUISITE CRITERIA OF THE PERIODONTIUM PRIOR TO INSTITUTING RESTORATIVE PROCEDURES

Prior to instituting restorative procedures, the supporting tissues involved with periodontal disease should be placed in a state of health. Restorative dentistry

should have as its basis a healthy supporting structure. Yet, how many times do we place extensive restorations on a diseased periodontal structure? Random clinical sampling will substantiate the fact that all too often the restorative procedures are completed without supportive periodontal therapy. In treatment planning, first consideration should be given to the supporting structures that will be called upon to carry and sustain the restorations. It follows then that we must plan a logical sequence of treatment. Proper treatment in logical sequence spells success. The following prerequisite criteria should be met and serve as a guide before restorative procedures are undertaken for patients who have been or are under periodontal treatment.[12]

1. Subjective symptoms should be controlled or eliminated: (a) pain, (b) odor (halitosis), (c) gingival bleeding, and (d) excessive mobility.

2. Objective symptoms should be eliminated: (a) elimination of gingival and periodontal pockets, (b) elimination of infection (cessation of hemorrhagic and purulent exudates), (c) arrest of bone loss, (d) elimination of architectural deformities of the periodontium (interproximal "craters," abnormal frenulum, etc), (e) elimination of occlusal disharmonies and the establishment of good function of the masticatory organ (teeth, muscles, and temporomandibular joint), and (f) elimination of excessive mobility (splinting, etc.).

3. Gingival health[14] should be restored: (a) color—pink, (b) marginal contour—thin, (c) papillary contour—pointed, (d) texture—stippled, (e) consistency —firm, (f) exudate—none, and (g) gingival crevice—shallow.

4. Etiologic factors should be controlled: (a) *local*—calculus, materia alba, defective restorative dentistry, etc.; (b) *systemic* (modifying factor) anemia, diabetes, etc.; and (c) *stress* (neurotic habits—clenching, grinding, nail-biting, etc.).

5. Hopeless teeth should be removed.

SPECIFICATIONS OF OCCLUSION

The better the function, the better the health of an organ or tissue. In other words, restorative dentistry, including a Class I restoration to the most complicated fixed or removable partial denture should be built to biomechanical requirements. Biologic mechanisms,[15] such as, (1) continuous eruption of the teeth, (2) continuous mesial drift of the teeth, (3) continuous deposition of cementum on the roots of teeth, and (4) continuous growth and resorption of alveolar bone must not be interfered with by restorative procedures. It should be the objective of restorative dentistry to replace missing or diseased hard tissues of the teeth and to promote good function. The better the functional specifications of restorations, the more efficiently the above biologic mechanisms operate. Overcontoured restorations (fillings and crowns), cuspal interference, and premature contacts interfere with ideal function (Fig. 12). These conditions may lead to periodontal traumatism and to interference with the masticatory organ (teeth and periodontium, muscles, temporomandibular joint). The better the harmonious function between teeth, muscles, and temporomandibular joint, the better the functional adaptation of the periodontium. This is especially important if the supporting tissues of the teeth are involved with periodontal disease. In the presence of periodontal disease,

even an ideal occlusion may become traumatic[16] (secondary traumatism). It becomes mandatory to eliminate occlusal interferences such as premature contacts, cuspal interferences, and unphysiologic restorations in patients afflicted with periodontal disease if we have any respect for biologic requirements. According to Orban,[17] the following biologic factors should be recognized in dealing with disturbances in occlusal relations: (1) Periodontal diseases are disturbances of the supporting tissues of the teeth. Occlusal disharmonies constitute a serious aggravating factor under such conditions. (2) The supporting tissues of the teeth are built according to functional requirements. The better the functional relation between mandibular and maxillary teeth in every position, the less the strain on the supporting tissues. This assures a most favorable tissue response to functional demands. Schuyler[18] also states the following objectives in achieving good occlusal relations: (1) equilibrate the occlusion and articulation of the teeth to harmonize with the musculature and the temporomandibular joint, (2) bring occlusal forces into the direction of the long axes of teeth, (3) distribute forces in eccentric positions to largest possible number of teeth, (4) establish a static relation between cusps and opposing fossae, (5) reduce the steepness of cusp inclines, (6) reduce the size of the contact surfaces, (7) retain the sharpness of cusps and establish smooth guiding planes, and (8) do not interfere with the rest position of the mandible.

Occlusal trauma is a factor in periodontal disease; however, the weight of evidence points to its role as being that of an aggravating factor (secondary). Experimental evidence reveals that inflammation is aggravated and spreads faster in the presence of simultaneous trauma.[19] From the practical viewpoint, we should not only achieve good function but we should prevent or eliminate trauma in those patients with periodontal disease who require restorative dentistry. Properly constructed restorations can prevent occlusal trauma. The opposite effect can also be achieved by the creation of occlusal trauma by improperly designed restorative procedures.

MUCOGINGIVAL FACTORS

Mucogingival architecture plays an important role in the functional interrelationship of the periodontium and maintenance of oral hygiene and, thus, periodontal health. It is for these reasons and this relation of the mucogingival complex to restorative procedures that these factors will be considered here. Several circumstances in periodontal therapy require mucogingival surgery.[20-23] These are: (1) pocket eradication in which the base of the pocket is apical to the mucogingival junction, (2) the loss of the attached gingivae, and (3) a high frenulum attachment (Fig. 13*A*). The implication of these situations with regard to periodontal pathology and the maintenance of periodontal health should be obvious. To resolve these situations calls for a reorientation of the mucogingival tissue. Surgical correction and reorientation calls for such procedures as frenectomy, gingival resection, flap operation, and other procedures known as "repositioning the attached gingivae," "gingival extension," and "extension of the vestibular fornix." In response to a surgically created new environment, newly regenerated gingival tissue

is formed.[24] The relation of these mucogingival conditions requiring treatment to restorative dentistry is of prime importance. Mucogingival problems associated with abutment teeth of either fixed partial dentures, crowns, and/or removable partial dentures require special consideration if a hygienic environment and periodontal health are to be achieved (Fig. 13*B*).

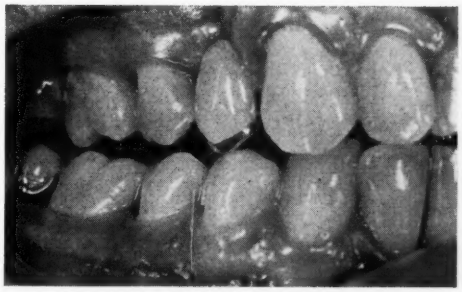
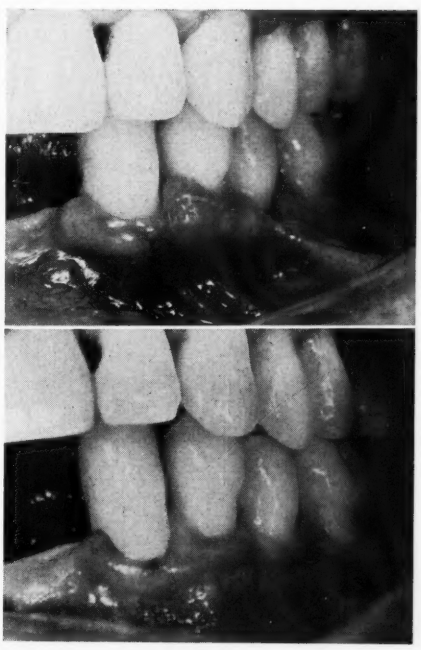


Fig. 12.—Teeth in lateral "working" occlusion. Note the cuspal interference of the bridge pontic. Conditions such as this lead to periodontal traumatism and interference with the functional harmony of the masticatory organ (teeth, muscles, temporomandibular joint).

A.



B.

Fig. 13.—*A*, The preoperative appearance of the teeth and gingivae of a patient with a mucogingival problem. There was a loss of gingival attachment, recession, a periodontal pocket with the base apical to the mucogingival junction, and a strong high buccal frenum. The tensional pull of the cheeks and elastic tissue of the mucosa aggravated the problem. *B*, The postoperative appearance of the teeth and gingivae of the same patient after mucogingival surgery. Treatment consisted of gingivectomy and a flap operation for extension of the gingivae. Note the improvement in the architectural specifications of the periodontium, the absence of tensional pull of the buccal frenum, and the new regenerated zone of gingivae.

CONCLUSIONS

1. Periodontal health is the basis of successful restorative dentistry. Conversely, proper restorative dentistry is a prime requisite in the maintenance of periodontal health.

2. Biologic mechanisms operate in the periodontal environment. Interference of these mechanisms may result from ignoring the periodontal specifications of restorative dentistry.

3. The design of restorative units may either exert a beneficial or regressive effect on the periodontium.

4. One can thus state the truism-Periodontics and restorative dentistry are not independent, not dependent, but *interdependent* and *interrelated* in their objective, that of the preservation of the natural dentition.

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MANDIBULAR MUSCLE SPASMS AND TEMPOROMANDIBULAR JOINT DISTURBANCES

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THE NOMENCLATURE ASSOCIATED WITH disorders which have been grouped under various names, such as Costen's syndrome and temporomandibular joint syndrome, has been a source of much confusion. Symptoms of conditions of totally unrelated etiology have been lumped together, and the terms used have either indicated nothing as to the etiology or the pathology involved, or they have been misleading. For this reason, I have introduced a new descriptive term, *mandibular muscle spasm*, which is self-explanatory and clearly indicates the nature of the process.[1]

There are two separate and distinct conditions involved: (1) disturbances of the temporomandibular joint itself, and (2) disturbances of the mandibular musculature. Unfortunately, each of these conditions, under certain circumstances, can produce the other, and this fact has further served to increase the already existing confusion. Mandibular muscle spasm is the more important clinical entity. Patients with this disorder will seek help most often and will need it most urgently. Of 12 patients with temporomandibular joint arthroses, 7 have complained of symptoms, and of these, 6 had muscle spasms. The reason for this is quite simple. The muscle spasms cause the patients more pain and difficulty and produce far more dramatic and frightening effects. Moreover, the patients who suffer from these muscle spasms are emotionally disturbed individuals and, as such, they are likely to react severely to any disease.

MANDIBULAR MUSCLE SPASMS

Anything which changes or interferes with the action of any of the muscles attached to the mandible will play havoc with mandibular function. Mandibular muscle spasms are a syndrome consisting of three salient symptoms: (1) pain, (2) mandibular dysfunction, and (3) emotional disturbance.

PAIN

As increasing numbers of patients with mandibular muscle spasms have been examined, it has become more and more apparent that the pain involved varies so much in location, intensity, and duration that no generalizations can be made except

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to indicate broadly its more common limitations. The pain of spasms of the mandibular musculature is myofascial in origin and can be referred anywhere in the head and neck. The patients will complain most often of pain above the eyes and in the temples and next often of pain on the side of the face. The pain is more frequently unilateral than bilateral. It may be of relatively short duration or it may last for days. One patient asserted that it had been present almost continuously for the preceding year. These patients are usually acutely disturbed, not only by the pain, but about the pain as well, and a careful sympathetic questioning will bring out the fact that almost all of them are fearful that these pains are symptomatic of some fatal disease. A number of these patients have described the pain as being within the bones themselves. The intensity of the pain varies widely from a dull ache to a severe pounding, and it may be mild at one time and severe at another.

If the mandibular muscles are palpated, they can be felt sometimes to be in spasm. At these times, they will be as hard as any muscle in contraction. More often, there may be only definite localized trigger areas palpable. On a few occasions, the patient has felt pain in the temporomandibular joint when these trigger areas were palpated. In many patients, the muscles involved feel sore or bruised. The muscle that is most often involved is the masseter muscle, with the temporal and the internal pterygoid muscles following in that order. In two patients, tender areas in the digastric muscle were noted. Thus, there may be spasms of the suprahyoid muscles as well as the muscles of mastication, and for this reason, I use the term mandibular muscle spasm rather than masticatory muscle spasm.

MANDIBULAR DYSFUNCTION

Mandibular dysfunction also is present, but it varies widely in degree. It may range from only a slight decrease in the total opening to an inability to open the mouth more than a few millimeters. There may be a deviation of the mandible to one side upon opening which may be very slight or very marked. Some patients' mandibles deviate first to one side and then to the other as they reach full opening. When the mandible deviates markedly to one side, palpation of the condyle through the external auditory meatus will reveal that the condyle rotates but does not slide forward on the side toward which the mandible deviates.

EMOTIONAL DISTURBANCES

Emotional disturbances must be understood in the light of their psychoanalytic implications. The mandibular musculature is used from earliest infancy to express emotion. The infant can accept or reject food, cry, laugh, and express love and hostility through sounds and, later in life, through speech. In the adult, we have the "organ language" to emphasize these connections: swallowing anger, choking down anger, gritting or gnashing the teeth, and many others. Certainly, therefore, we should not be surprised to find emotional disturbances exhibiting themselves in clenching and grinding of the teeth and, either resulting from this or occurring independently, spasms of the mandibular musculature. However, only certain of the emotionally disturbed patients will somatisize in this manner, and we must be careful to evaluate any emotional disturbance in the light of the total patient.

TEMPOROMANDIBULAR JOINT DISTURBANCES

Temporomandibular joint disturbances can be classified as: (1) traumatic, (2) neoplastic, (3) infectious, and (4) arthritic.

Traumatic disturbances occur as the result of an injury, and a history and simple clinical examination usually will suffice to place the disturbance in this group. There is pain, swelling, limitation of motion, and muscle spasm.

Neoplasms of the temporomandibular joint are relatively rare, and when they occur, they usually do so as metastases from some primary tumor elsewhere. The symptoms they produce are capable of simulating other conditions, but roentgenographic examination of the joint usually will reveal their presence.

Infections of the joint are also rare, and they are usually extensions from an infectious process in the neighboring structures. There is limitation of motion with pain and swelling, and there may be systemic symptoms of infection.

Arthritis of the temporomandibular joint is either rheumatoid arthritis or degenerative joint disease. Rheumatoid arthritis is a systemic disease in which the temporomandibular joint may be involved as may any other joint in the body. Fortunately, it does not frequently involve this joint. It is diagnosed from the systemic findings, and a roentgenographic examination will show fusiform swellings and destruction of the articular structures. Fibrous or bony ankylosis of the joint may lead to disuse atrophy of the bones involved.

Degenerative joint disease has been defined as "a chronic arthropathy characterized pathologically by degeneration and hypertrophy of cartilage and bone, and clinically by pain, which occurs generally on use and is relieved by rest. It occurs chiefly in older individuals, usually in weight-bearing joints or the terminal interphalangeal finger joints. In general, it is unaccompanied by systemic manifestations."[2] The changes in this disease are degenerative in nature, and so the American Rheumatism Association has accepted the descriptive term "degenerative joint disease" as preferable to the more commonly used term "osteoarthritis."

Degenerative temporomandibular joint disease has been discussed previously[3] and is by far the most common joint disturbance. It is far more widespread than is generally recognized. Out of 20 patients selected at random from among those being treated at the arthritis clinic, 12 had temporomandibular joint disease. It is of course impossible to draw any conclusions at so early a stage in this study, but it does indicate the frequency of this condition.[3]

The symptoms of degenerative temporomandibular joint disease are threefold; namely, pain, stiffness, and joint sounds. The pain is usually a dull, aching type which is referred to adjacent regions. There may be swelling and tenderness over the joint. There is stiffness, and this is more marked after a period of disuse, as when the patient arises in the morning. There are also clicking, snapping, or grating sounds in the joint. The diagnostic value of roentgenography is definitely limited because of the anatomic difficulties involved in making roentgenograms of this joint. A negative roentgenogram certainly does not rule out degenerative joint disease, and the clinical findings would be the deciding ones in these patients. The long cone technique[4] appears to give the most satisfactory roentgenographic visualization of the joint.

Degenerative temporomandibular joint disease is by far the most common of the joint disturbances, and this article will be limited to a discussion of this one condition.

DIFFERENTIAL DIAGNOSIS

The symptomatology of mandibular muscle spasms and degenerative temporomandibular joint disease has been described, but a differential diagnosis can be a difficult and uncertain thing. Two facts complicate the diagnosis: first, mandibular muscle spasms, if continued, will inevitably lead to joint disease; and second, joint disease can throw the muscles into spasm. It is of the first importance to know which came first. If joint disease is causing the muscle spasms, relieving the pain of this condition will clear up the spasms. However, if the primary condition is muscle spasm, we are faced with a strange phenomenon. Relieving these spasms often elicits more pronounced symptoms of joint disease. This probably occurs for two reasons: first, the muscles in spasm reduce the amount of joint movement and so minimize the symptoms of joint disease; and second, the pain of muscle spasms overshadows any other pain which may be present.

A carefully recorded clinical history is the basic element in making any differential diagnosis and may indicate the diagnosis quite clearly. We should search particularly for any evidence of clenching or grinding of the teeth since this occurs at a subconscious level, and the patient may be totally unaware of it. Calling this fact to the patient's attention may lead to a confirmation of our suspicions at a subsequent visit, because the patient would have been looking for clenching or grinding. However, beware of the patient who dates his difficulties from what he describes as an accident, i.e., a sharp crack in one of the joints during some mandibular action. This is often purely functional and may not represent any organic change, such as a dislocation. It results from the mandibular muscles going into spasm and exerting a sudden unbalanced pull on the condyle and articular disk, thus violently disturbing their relationship and producing the sound the patient hears.

The fact that a patient is emotionally disturbed also must be evaluated with care, for it does not mean that the patient is somatisizing his difficulties in this manner. The differential diagnosis often will resolve itself into a matter of clinical judgment and experience, for there are no objective scientific tests available.

TREATMENT

The treatment of mandibular muscle spasm is twofold: first, to relieve the muscle spasms in order to provide symptomatic relief; and second, to provide as much emotional help as we can give the patient. These patients are emotionally disturbed individuals with many fears and anxieties. For this reason, anything which would tend to aggravate their emotional problems or increase their anxieties must be carefully avoided.

Injections of local anesthetics into the muscles are emotionally traumatic, and so an ethyl chloride spray is used to relieve the pain and provide immediate relief.

The spray bottle is held just far enough from the patient so that there is no whitening of the skin. It produces a refrigerant effect. The spray is directed in long, slow, sweeping movements over the muscles involved until the pain is relieved. Oddly enough, when this is done to one muscle in spasm, the spasms of other muscles also seem to be relieved. I can offer no explanation for this beyond the fact that anything we do has an emotional effect on the patient. With the relief of the pain, the mandibular dysfunction is always reduced to a greater or lesser extent. This relief is most important because it gives the patient definite proof that he is being treated properly, and it relieves his anxieties about having some fatal undiagnosed illness. It also makes it possible for the patient to accept our diagnosis.

For long-range relief, physical therapy is of great value. Moist heat and exercises are prescribed for home care. The heat is to be applied to the muscles involved four times daily for 30-minute periods by means of wool or flannel cloths which have been soaked in hot water. After the heat has been applied for about 10 minutes, the patient is instructed to exercise his muscles by slowly opening his mouth as widely as he can about a dozen times, and then to open his mouth partially and move his mandible gently from side to side about the same number of times. This stretches the muscles and relieves the spasms. When the muscles remain in a state of contraction for long periods of time, contracture takes place and the muscles are shortened. These exercises help to restore the muscles to their original length.

Analgesics, particularly the salicylates, are of great value in relieving the pain. Muscular spasms are self-perpetuating conditions, for the muscular spasm produces pain which then throws the muscle reflexly into more violent spasm, producing more pain, and so deeper and deeper into this vicious cycle. It must be remembered that we are dealing with emotionally disturbed patients, and drugs must be prescribed with care, particularly when barbiturates and narcotics are used. The new muscle relaxants are useful for certain patients.

Reassurance is absolutely essential for these patients, and this can be provided by a calm confident diagnosis which is proved by the relief provided for the patient. A long conversation with the patient may be used to encourage him to verbalize at least some of his problems and, thus, provide him with some relief. At the same time, we can gain an insight into the patient, and this will help us to give him the reassurance he is seeking. It is most important that the patient accept the fact that these muscle spasms are on an emotional basis. On several occasions, this has proved to be all that was necessary to clear up the spasms and pain. It may be quite useful to make the patient aware of clenching and grinding his teeth, for he may then be able to consciously control these habits and, thus, prevent the muscles from being thrown into spasm. However, I am treating a patient who is most unhappy that she is getting relief, and she took great delight in calling me to tell me she was having pain again. Obviously, the prognosis is very poor for her because the pain serves a very definite need, and the patient wants to retain it. She absolutely rejects the suggestion that it is on an emotional basis.

Dental treatment should either be avoided or be kept to a minimum until the muscle spasms are well under control. Occlusal reconstructions or changes in vertical dimension of occlusion are very treacherous procedures and may lead to all sorts

of complications. Even when the spasms have been cleared up, dentistry for these patients always will carry the seeds of potential trouble and should be limited to the essentials. Dental operations should be performed in short visits with great care being paid to the psychologic handling of the patient. Any traumatic occlusion should be relieved, but even this may be enough to throw the patient back into difficulties. It cannot be emphasized too strongly that conservatism in dental treatment is essential to the well-being of these patients, and radical procedures should be avoided at all costs.

The treatment of degenerative joint disease is basically a matter of rest, heat, and analgesics. The amount of rest that can be given to the temporomandibular joint obviously is limited, but we can relieve the trauma by correcting any traumatic occlusion and, where necessary, restoring the vertical dimension of occlusion to its correct physiologic level. It should be remembered, however, that a certain amount of loss in vertical dimension with age is physiologic and not pathologic. Moist heat should be applied four times daily, and salicylates are the best analgesics in this condition.

PROGNOSIS

The prognosis in mandibular muscle spasms is uncertain. Many of these patients can be helped, but the amount of help given will vary widely. Even when the treatment is successful, these muscles may be thrown into spasm at any time. Only psychotherapy can clear up the underlying problems for these patients.

The prognosis for degenerative temporomandibular joint disease is favorable, and a good functional result can be anticipated. When the disease reaches its final stage, the pain will disappear, and the patient will be comfortable.

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OPERATIVE DENTISTRY

MODERN ASPECTS OF OPERATIVE DENTISTRY

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THE FUNDAMENTAL PURPOSE OF dentistry is to preserve or to restore the natural dentition to health and function. However, often the very damaged dentition is beyond repair, due to negligence of the patient, so that surgery and prosthesis are necessary. However, the public is becoming more health-minded, and the dental care is commonplace. It is gratifying to note a growing demand for dental service for the preschool child as well as for the older brother and sister.

With such a favorable patient-dentist relationship as exists, dentists must assume the role of consultants in matters of prevention, and each operative dentist should have the ability to perform those procedures which involve endodontics as well as restorative dentistry.

It is embarrassing to receive a child as a patient who has not received the attention or the skill of his dentist. In some cases, there is evidence of gross neglect which has resulted in pulp degeneration due to unprotected vital pulpal tissue from irritating filling materials. There are some in our profession who openly profess that they are not interested in endodontics. I suggest that these dentists refer patients needing endodontic service to competent dentists, who perform such services.

THE CARIOUS TOOTH

It is common practice to make roentgenograms of the teeth before operative procedures are commenced. This is true for small children as well as adults. Much can be determined from the roentgenograms as to the extent of carious destruction and the reaction of the pulpal tissue to this disease. The decayed area may be very shallow, and this necessitates the removal of the caries and the preparation of the cavity. The deeper cavity offers the problem of pulpal protection and more careful preparation. Extensive carious lesions can result in three conditions: (1) the pulpal tissue has responded by recession and fortification by the formation of dense secondary dentin; (2) there is no evidence of pulpal reaction but sound dentin apparently still protects the pulp; (3) the carious destruction reaches the pulp.

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THE DRY FIELD OF OPERATION

The use of the rubber dam to keep the field dry during preparation of the cavity is without doubt one of the greatest aids in operative dentistry. Without this procedure, it would be impossible to perform adequate endodontic treatment. This protection from the fluids of the mouth aids in complete carious removal and in the design in the cavity, such as the depth, retention, and outline form. The application of a suitable pulp protective base is made easier if a rubber dam is used.

PULPAL PROTECTION

There are some differences of opinion about the necessity of using a cement base for amalgam fillings. Markley[1] is of the opinion that if no excessive heat is produced during cavity preparation, there will be no evidence of sensitivity after a filling is placed. Roper[2] noticed severe pulpal reaction to new amalgam restorations in the mouths of members of the United States Air Force when at high altitudes. This reaction was not experienced with fillings that were built in cavities that had a protective base material covering the newly cut dentine. Extreme galvanic and thermal activity has been noted in nonbased amalgam restorations in teeth that are young and also in teeth of older patients that have not been filled previously.

BASE CEMENTS

The most efficient base is zinc phosphate cement. It will adapt itself to the part of the cavity where it is necessary, and it will adhere to the tooth structure. When set, it is strong enough to withstand the forces required to condense the filling material. Its setting time can be modified by the way it is mixed and spatulated. It is the easiest cement to apply, since it can be flowed in place accurately on an explorer point, or it can be packed into the cavity. It can be strengthened by the addition of alloy filings and, with this change in structure, it can be shaped by cutting instruments. Also, the cement-alloy mixture provides a more lasting temporary filling.

Mosteller[3] warns us about the indiscriminate use of zinc phosphate cement. It has been his experience to observe pulpal reaction from the cement applied to unprotected dentin. He suggests the use of equal parts of cement liquid and eugenol, spatulation with cement powder, in the usual manner, to a thick consistency, and packing the cement in place. He believes that the eugenol offers a protection to the pulpal tissues from the acidity of the orthophosphoric acid of the cement liquid.

Zander,[4] in his study of the pulpal reaction to silicate cements, found that cavity varnishes were not impervious to the cement acid. He found, however, that the use of zinc phosphate cement stimulated the formation of irregular dentin and used this material as a temporary filling for a few months before inserting the silicate restoration in anterior teeth of young patients.

Many inlays and crowns are cemented in place with zinc phosphate cements, and these restorations give years of service, and the pulpal tissue seems to remain in

a healthy state. When pulpal degeneration occurs, it can be the result of the caustic action of the orthophosphoric acid of the thin cement mix which was forced into the dentin when the inlay or crown was pressed in place. It seems reasonable that varnish should be employed before cementation.

Zinc oxide and eugenol paste can be accelerated to serve as an immediate base, but experience has demonstrated that it does not have the strength to withstand the packing pressure required for amalgam.

THE DEEP CAVITY

The deep cavity can present a serious problem. Due to the close proximity of the vital pulpal tissue, the protective base should serve two purposes. It should be nonconductive and should act as an insulator. It should be of such a nature that it can stimulate the formation of secondary dentin to some extent. When the cavity is very close to a pulpal horn, it is good practice to apply calcium hydroxide first and then cover it with a suitable base.

MECHANICAL EXPOSURE

It is possible to cause a mechanical exposure in this type of cavity, but with careful procedure, it does not happen often. However, in those teeth where exposures are made, it is best if the tooth is in a dry field so aseptic measures can be taken to treat the exposure. The application of a calcium hydroxide and distilled water paste to the exposed pulp is suggested. This is covered with a suitable cement base which is flowed into place. At no time should pressure be exerted which could have an irritating effect on the vital pulp tissue. Some success can be expected if this procedure is carefully executed. However, this condition must be considered as a temporary procedure, and a good temporary restoration should be used until the time when roentgenograms show dentin regeneration.

CARIOUS EXPOSURES

Carious exposures present a very serious problem. There is always the tendency to preserve the vital pulp tissue. The claims of some manufacturers, in regard to regenerative powers of their therapeutic paste or cement, have influenced some dentists to depend upon these agents to regenerate dentin rather than to use some procedure that is less empirical. When the carious infection has reached the pulp, there are only two proved methods of treatment. Where the roots of the teeth are not completely formed, it is not possible to do a complete pulpectomy. If, in these teeth, the pulp has not degenerated beyond the coronal portion, it is possible to remove that portion of the pulp and leave the vital tissue undisturbed in the root or roots and to hope for their complete formation. This is commonly known as pulpotomy or partial pulpectomy, and it is commonly practiced in pedodontics. It must be emphasized that the success of this procedure depends largely upon a proper diagnosis. A degenerated pulp can be *expected* to fail. However, a pulp that has caused no previous pain and a hemorrhage that is natural in color and flow during the removal of the pulp are indications that are favorable.[5] A

comprehensive study of the pulpotomy technique[6] gives the dentist the ability to deal with fractured young anterior permanent teeth that have resulted in pulpal exposures.

The other proved method of treatment of pulps exposed by caries is to remove the pulpal tissue, treat the root canal, and fill it to the apex. There is no reason why the average dentist cannot have sufficient knowledge of endodontic procedures to treat anterior and other single-rooted teeth. He should be able to cope with putrescent and abscessed anterior teeth. However, the pulpectomy involves the use of absolutely aseptic procedures for success. The habitual and routine use of the bacteriologic incubator to detect sepsis of the pulp chamber and the canal is necessary for positive success.

QUESTIONABLE PRACTICES IN RESTORING TEETH

The design of cavity preparation and the technique for building fillings[7] has been such as to save teeth, as nearly as possible, for the life expectancy of the patient. Formerly, the average life expectancy was under 40 years. At present, the average American lives to be nearly 70 years of age. It is questionable whether the life expectancy of restorations can or should be our responsibility. We should weigh the practices of severe gold foil condensation with its possible traumatic results and lasting qualities of these restorations, with the possibility of modifying this restorative material with the cushion effect of noncohesive foil or mat gold. In the interproximal surfaces of anterior teeth, is it not a safer procedure to eliminate extensive cavity preparation for convenience and prevention and to use materials which may have to be replaced after a few years?

The same can be said about the cavity preparation for the gold inlays. We are aware that the inlay demands more extensive cavity preparation than the amalgam filling. It is true that the inlay has its definite place in restorative dentistry. It is questionable, however, if it should be used routinely as a filling material. When we consider that the average dentition demands constant repair, it seems reasonable that less extensive restorations are more reparable. The biologic approach in restorative dentistry should be our first consideration. The removal of all carious matter and the serious consideration of the health of the pulpal tissue is our responsibility.

THE SELECTION OF FILLING MATERIALS

The dental profession does not have many dimensionally stable filling materials. Most materials used are subject to volume changes. Cast gold restorations rely upon cementation for sealing the cavity, and this is a natural weakness. The technical procedures which involve the formation of a wax pattern that has definite variables demand a painstaking technique to result in a suitable casting. For this reason, the cast gold inlay is costly and may be beyond the budget of the person of moderate means.

The serious and responsible dentist is interested in restoring the teeth of his patients with materials that are capable of giving years of good service. Also, this

same dentist is concerned with giving this patient dental service that he can afford. It is good business to render satisfactory dentistry at a satisfactory cost. Only in this manner can a practice grow and be a pleasant profession.

GOLD FOIL AND SILICATE CEMENT

Gold foil is the ideal filling material. If one considers the time consumed in building gold foil fillings in the interproximal cavities of the anterior teeth, such service must be costly, and it can be a service to a limited number of patients. The dentist who is trying to give good service to the greatest number of patients is to be complimented. He is trying to do what is demanded from our profession.

There are some dentists who condemn the use of silicate cements and praise the superior gold foil restorations to the utmost. When one considers that the gold foil filling can be either the best or the worst filling, it is a matter of concern whether the average dentist would be rendering a satisfactory service with these restorations. The silicate filling has saved more teeth than all the gold foil fillings in the world. Silicate cement is dangerous because of its extreme acidity, and pulpal protection is essential to success. Silicate cement fillings have one redeeming quality when they are properly made. Recurrent decay seldom occurs under silicate fillings. Silicate cements should be used only in the proximal surfaces of the anterior teeth. It should not be used in gingival cavities, since it will wash out when it is in contact with the gingival gum tissue. It is good practice to use gold foil in gingival cavities of the anterior teeth as well as in first bicuspids. Such a procedure takes only a few minutes, and it will result in a restoration of superior quality and esthetics.

PLASTICS

The advent of the self-curing acrylic resinous filling is the result of the demand for a filling material with a toothlike appearance and durable qualities. Due to its high coefficient of expansion,[8] it is the most questionable filling material used to replace silicate cements in the proximal of anterior teeth where it is used more frequently. Although this material *seems* to be less difficult to manage and to fill cavities than some other materials, the proper technique for applying the resinous filling material to the cavity is slow and arduous. The percolation of the mouth fluids between the margins of the filling and the cavity walls frequently results in recurrent decay and pulpal degeneration. If this material is to be used in Class III cavities, as well as elsewhere, it is a safe procedure to protect the pulp with a cement base.[9] The self-curing resinous fillings can give suitable results in the gingival cavities in anterior teeth and bicuspids where esthetics are important. The free gingival tissue and the labial and buccal apposition of the lips and the cheeks are a stabilizing thermal influence, and the filling is not subject to the thermal effects of hot or cold foods or liquids. The operative field must be dry, and the gingival tissue must be held away from the cavity by a rubber dam and a gingival clamp.

After serious research, a plastic filling material may be developed which will possess the necessary qualifications to make it a superior restorative material. At

the present time, it is our duty to resist the claims of some manufacturers that their plastic filling materials are superior to amalgam for posterior restorations.

AMALGAM

Amalgam had dominated the filling materials for posterior restorations for many years. It is a material of many variables. Its linear coefficient of thermal expansion is more than twice that of the coronal portion of the tooth. It has a tendency to flow under stress. Its strength is determined by the ratio of mercury to the alloy, trituration, and condensation. Moisture contamination will cause expansion of amalgams containing zinc. As a result, it is necessary to use a careful technique to except good results.

Amalgam is abused and misused and still has the unique position of being a fair material no matter how it is used. An explanation of this result is the research of Nelsen, Wolcott, and Paffenbarger,[8] who, in their study of the fluid exchange at the margins of various filling materials, found that amalgam fillings that have been in the mouth for some time showed a chemical barrier at the margins that prevented percolation of mouth fluids under the margins. Markley,[1] in his observation of the inlay versus the amalgam filling, suggested that "an amalgam filling is usually much better than it looks, while a gold inlay is seldom as good as it looks." Enough research has been employed to give the average dental practitioner enough clinical evidence to use a procedure which can and will result in superior amalgam restorations.

SUMMARY

The biologic approach to operative dentistry is our primary responsibility. The health and functional integrity of the restored teeth must preclude radical techniques and designs for permanent performance of restorations. It must be considered ideal for restorations to function during the lifetime of a patient. It is doubtful, however, that dentistry can assume that responsibility. Continuous dental service rendered to our patients, starting with the very young, is the best insurance for the retention of their natural dentition.

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EVOLUTION OF TOOTH CUTTING TECHNIQUES AND ITS INFLUENCE ON RESTORATIVE DENTISTRY

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IT HAS BEEN STATED that "efforts in cavity preparation were primitive until Singer and Howe developed the sewing machine, which served as a model to inspire Morrison to develop the dental engine in 1871."[1]

In order to establish a background showing the development of tooth cutting techniques, we must first understand that many instruments used by dentists for cutting tooth structure previous to the invention of the dental engine had to be made by the individual dentist to suit his own particular needs.

As a means of orienting our thinking on this subject, let us start with the year 1840. This was the year that organized dentistry, as we understand the term, began. It was the year of the founding of the first national dental society, The American Society of Dental Surgeons. It was also the year of the foundation of the first dental school, the Baltimore College of Dental Surgery. While these events opened up a new avenue of dissemination of dental knowledge, progress was very slow in improving methods of cutting tooth structure. Up to almost the beginning of the present century, dentists here and there were still using drills and burs rotated by the fingers in an effort to prepare cavities in teeth.

In 1846, a finger ring and drill socket were designed by A. Westcott. Also, in 1846, a dental drill was devised by J. Foster Flagg. This was the first drill to be generally accepted by American dentists. In 1858, a device called Merry's drill was introduced. This was considered to be a great advance over methods used up to that time. The introduction of the dental foot engine by Morrison, in 1871, will always be an important date in dentistry's history. It was the key that opened the door to a new concept of tooth cutting techniques. During the period 1870-1874, Green[2] developed the first electric dental engine. Then followed improvements, such as the folding bracket type engine in 1902, and other minor changes. In 1914, the S. S. White Company brought out their Forsyth unit, which was the first of the unit type of dental engines. It is interesting to note that from about the turn of the century to the period beginning with the end of World War II, no outstanding improvements were made in the dental engine. They were reliable, needed little servicing, and the engine speeds seemed to be sufficient for the cutting tools

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then in use. It could very well be that because they needed so little attention, nobody thought to improve them. Of course, there were improvements as to form and appearance, but basically they remained pretty much the same.

Just before the outbreak of World War II the Germans developed diamond cutting instruments for use in dentistry. These instruments were immediately accepted by dentists, for they seemed to offer great promise in cutting tooth structure more efficiently than the steel burs and Carborundum points that had been used. It was not long before it was noted that these diamond instruments cut better when they were run at greater speeds, but due to the outbreak of World War II, little was done about it.

When we review the history of crown and bridge work, we are struck by the fact that the lack of an efficient means of removing tooth structure and forming preparations was a real drawback. In order to appreciate this, we have only to obtain a sound tooth that has recently been extracted for reasons other than caries involvement, then to try to make an entrance through the enamel without the aid of the dental engine. Not a great deal of imagination is required to visualize the difficulty of trying to form the most simple type of cavity preparation. It is hard for us, today, to accept the fact that G. V. Black[3] did not have a dental engine to work with when he opened his office in 1864. His armamentarium consisted mostly of chisels, excavators, and hand drills.

With Morrison's invention of the dental engine, the field of crown and bridgework opened up. Better abutment preparations were possible, although the end results were still nothing to brag about. Wholesale removal of pulps came into vogue, and the gold shell crown blossomed forth. A number of patents were obtained, such as the one on a gold crown in 1873, and the Richmond crown in 1880. Soldering processing patents had also been secured.

About this time a group called "The International Tooth Crown Company"[4] was formed, having acquired title to over twenty-five patents covering the making of crowns and bridges. This company sold licenses to dentists for the privilege of practicing crown and bridgework, charging anywhere from $100.00 to $500.00 per year. Dentistry has Doctor J. M. Crouse and a few of his courageous followers to thank for the fact that the control of the practice of crown and bridgework by the International Tooth Crown Company was finally broken up by the courts in 1900, when all of the crown and bridge patents were invalidated. Doctor Crouse won his fight, but was ruined financially.

CAST GOLD RESTORATIONS

It was not until 1907, when Doctor William H. Taggart[5] read his paper, "A New and Accurate Method of Casting Gold Inlays," that full advantage was to be taken of the dental engine's potentialities. The casting process made possible many of the restorations we make today, such as the ¾ and the full cast gold crown, and all types of veneers and inlays used in crown and bridgework. There is no doubt but that the invention of the casting process opened up a new concept in restorative dentistry. However, in order to take full advantage of this new technique, a better method of cutting tooth structure was still needed. It is a rather

amazing thing, in reviewing the over-all picture since that time, to be brought to the realization that nothing much was done about improving the dental engine, the handpiece, or the cutting tools until the introduction of diamond instruments just previous to World War II. Those of us who have been in practice long enough to evaluate the situation can vouch for the fact that only a small percentage of dentists took immediate advantage of the casting process.

During the mid-twenties, I had occasion to take a postgraduate course in precision attachment work. This course served to stimulate my interest in cast gold restorations as this type work required them for abutments. In spite of the fact that the casting process had been available for a number of years, not many cast gold restorations were being made then. An exacting type of preparation was required which necessitated longer appointments. Many times patients would object to the necessarily longer exposure to what they termed "the drill." In most instances, what they were really objecting to was vibration. The use of Carborundum disks, stones, and steel burs running at speeds of 3,000 to 6,000 r.p.m. was most unpleasant, to say the least. This was the speed range in general use at that time. Peyton and Henry[6] have reported that the amplitude of vibration at the handpiece is greater at speeds between 3,000 and 6,500 r.p.m. than at any other speed. Walsh and Symmons[7] found that vibrations produced in handpieces rotating up to 5,000 r.p.m. are close to the range of maximum vibration sensitivity in teeth. Our methods used in the preparation of porcelain jacket crowns, where a shoulder preparation was required, seemed particularly inadequate when steel burs were used at these speeds.

In 1947, Sears[8] introduced the hydrocolloid technique. As this method was basically an inlay technique, it served to further impress upon us the need for a better means of preparing and cutting cavities in teeth with less patient discomfort.

With the introduction of the diamond type of cutting tools, the picture began to change. There was a noticeable increase in the use of cast gold inlays and fixed bridgework. Of course, there was still the problem of vibration, but this had been lessened due to the fact that the diamond points could remove tooth structure and shape our preparations more efficiently.

When we review, objectively, the type of restorative dental services being rendered as time goes on, there is one fact that seems to stand out; as we have devised better tooth cutting techniques, we have been enabled to produce better finished results, both functionally and esthetically.

THE AIRBRASIVE TECHNIQUE

In 1945, Black[9] brought out the airbrasive technique. At that time he stated, "The reason considerable pressure is required to obtain cutting action by means of burs and stones is that the surface speeds of these instruments are slow." Here is a fact that had been generally overlooked. Black's Airdent unit was developed and finally offered to the dental profession in 1951. A postgraduate course of instruction was demanded before a dentist was allowed to purchase one of these units. Preliminary work in these courses was done on soapstone blocks and extracted teeth. Later, the students moved to the infirmary and had the opportunity

of preparing cavities in the teeth of patients. One could not help but be impressed by the high rate of patient acceptance of this method of cavity preparation which eliminated vibration. They were quite willing to sit for extended appointments and only seemed to be concerned as to whether or not all of their work could be completed before the termination of the special course. However, a number of disadvantages existed, such as keeping a clear field in the mouth mirror, and ineffective cutting of soft carious tooth structure and metal.

While the airbrasive method has not been too widely accepted by dentistry, Black's work was the spark that started a chain reaction in developing better methods of cutting teeth. The fact that vibration could be eliminated stimulated thought in that direction. The airbrasive technique also permitted the cutting of tooth structure without heat development which served to impress upon us the need for better temperature control.

BURS, STONES, AND HANDPIECES

In 1947, the S. S. White Company brought out carbide tipped burs. The efficiency of these new cutting tools was soon recognized. It became apparent that greater rotational speed was needed in order to have them work at peak efficiency. The cutting ability of these new burs, coupled with our experience in the use of the diamond instruments, accelerated the demand for greater engine speeds. At this point, let us be reminded of the fact that while we speak in terms of revolutions per minute, in referring to handpiece speeds, a very important factor is surface speed in feet per minute. There is a great deal of difference in peripheral speed of small and large cutting tools.

In 1949, Walsh and Symmons[10] reported that "stones and diamond instruments remove enamel approximately three times as fast at 60,000 rpm as at 3000 rpm and at 1/30th of the pressure." They also stated that "using stones and diamond instruments, the combination of high speed and low pressure, is from three to five times as efficient as low speed and high pressure." They found that the light touch that was needed gave greater ease of control with less danger of slipping off the tooth. In 1949, Larsen[11] stated that "the cutting ability of diamond instruments increases as the number of revolutions is increased. Peak grinding efficiency is reached with slight pressure."

In order to gain the obvious advantages of increased operating speeds, dentists began shunting out the motor resistors and increasing the pulley size on the motor shaft. Speeds of handpieces went up, creating greater problems of heat control. Our handpieces had been operating with gears. They now required more lubrication and could not be run for long periods of time without being cleaned, re-oiled, and greased. Straight ball bearing and highly polished glass-sleeve bearing handpieces began to make their appearance. In 1945, the Chayes Dental Instrument Company had placed a straight handpiece on the market using two highly polished glass-sleeve bearings. This handpiece could be used at speeds of 20,000 to 25,000 r.p.m. and above, but we did not have a contra-angle handpiece that could be used within this speed range.

In 1953, Densco, Inc. brought out their first ball bearing handpiece. This was a straight handpiece, and some of the working parts were held to tolerances under one-half of 1/1,000 of an inch. To the best of my knowledge, this was the first complete ball bearing handpiece, and it could be used up to 25,000 r.p.m. and above. They also made use of a long sheathed contra-angle handpiece, which, however, was still gear-driven and could not be run at speeds higher than 12,000 r.p.m. Contra-angle handpieces could be used with the standard right angle type of bur, the latch type. A contra-angle sheath could also be purchased that accommodated the tapered shank bur. With the use of this equipment, the increase in speed resulted in less pressure being used, which increased patient comfort. Need for more frequent attention to oiling and greasing was evident, due to the higher rotational speeds. About this time it began to be brought home to us that the next development in handpieces would involve the contra-angle type, which was still gear-driven, and that if higher speeds were required, new designs that would eliminate this obstacle would have to be forthcoming. It is interesting to note that when increased speeds seemed to be called for, the tendency of manufacturers was to change their straight handpiece design to accommodate greater speeds, but they neglected the contra-angle handpieces. Sleeve bearing and ball bearing straight handpieces were designed which permitted greater speeds, and at this time, it seemed almost impossible to expect that we could ever have a contra-angle handpiece that could be used with speeds operating within the range of the straight handpiece. As many of our operations are performed with contra-angle handpieces, it just did not seem to make much sense in trying to develop speeds which could only be used with the straight handpiece. In 1954, the Kerr Dental Manufacturing Company introduced to the United States a handpiece made in Germany, called the Imperator. This was a beautifully machined piece of equipment which reduced the vibration problem due to the precision fit of the various parts. Up to this point, our speeds had reached, mostly through the aid of ball and sleeve bearings, speeds of 15,000 to 25,000 r.p.m. with the straight handpiece. With the introduction of the Imperator, speeds in the neighborhood of 25,000 r.p.m. and over could now be used with the contra-angle handpiece. The precision cutting tools used with the Imperator were slightly larger and somewhat awkward to use in some areas of the mouth. Later, a smaller contra-angle head, and the instruments to go with it, was developed which overcame this objection. By 1955, S. S. White, Mid-West, and others began to produce ball bearing contra-angle handpieces. These contra-angle handpieces operated in the neighborhood of 20,000 r.p.m. and above. However, all the above-mentioned instruments required a great deal of care in the matter of lubrication. In 1955, Peyton[12] stated, "It seems doubtful if operating speeds of more than 12,000 to 15,000 rpm offer much practical advantage, in comparison to disadvantages that may be encountered." Peyton further stated, "The most practical range for speed still seems to be 12,000 to 15,000 rpm, an increase from the conventional 4,000 to 6,000 rpm previously employed. Further refinements in equipment may shift the optimum of speed upward in the future." At this time the development of handpiece speeds was in a state of flux. The so-called high-speed instruments available

at that time did not seem to be particularly more desirable than some of the lower speed handpieces, and it seemed that we had only increased our upkeep problem without proportional benefits. We had only scratched the surface, and the concept of working beyond the vibration perception of the patient was about to become a significant factor in our thinking. We had reached a point where contra-angle handpieces could be run at speeds in the neighborhood of 20,000 to 25,000 r.p.m., but the benefits gained did not outweigh the disadvantages of the added care and the constant lubrication problems that increased tremendously as the speeds went up. Most certainly the type of contra-angle handpiece being marketed did not seem to be the answer, in spite of the fact that a number of manufacturers produced various designs in an effort to solve the problem of frictional heat control in these instruments.

TEMPERATURE

With the introduction of high-speed rotational tools for tooth cutting purposes, articles began to make their appearance in the literature emphasizing the importance of heat control in relation to pulp tissue safety factors. Much of the work of authors, such as Henschel,[13] Vaughn and Peyton,[14] Hudson and Sweeney,[15] and others, writing on this subject was performed at a time when handpiece speeds were comparatively slow, but their principles of pulp protection through thermal control applies to any speeds used today.

When we think of rotational cutting instruments, the problem of frictional heat immediately comes to mind. The control of this heat in relation to pulp tissue tolerance should be of paramount concern at any speed. Of course, to a great extent, we have substituted speed for pressure which, in itself, cuts down the heat of any rotational instrument, but the need for its control is still extremely important. During my early years in dentistry, I can well remember the feeling of revulsion that I would have in cutting teeth with the so-called "heatless" stones and the preparation of cavities using steel burs. Both left much to be desired. A great deal of pressure was necessary in their use, and the vibration and heat factor was high. How could I help but think that there must be a better way, that our methods were very, very crude?

I consider myself fortunate in having been associated, when I first started practice, with a man who impressed upon me the necessity of keeping teeth wet when making preparations by using a stream of water directed on the cutting tool and tooth. In those days, this was done by cutting the stem off an ordinary bulb syringe close to the bulb, and with a certain amount of acquired dexterity, it was possible to keep a steady stream of water flowing over the operative field, one hand holding the bulb and the cheek while the other hand operated the handpiece. Later on, I used a pear-shaped ear syringe until the introduction of our automatic methods of delivering a stream of air and water to the tooth. At first, this was patient-controlled, and now we have means whereby we can govern the air and water stream through the foot control of the engine. Peyton* stated,

*Peyton, F. A.: Effectiveness of Water Coolants with Rotary Cutting Instruments, Read before the American Dental Association meeting in Atlantic City, N. J., Oct., 1956.

"It was observed that small diamond instruments and carbide burs are quite effective when operated at 30,000 to 170,000 rpm with only a four-ounce force applied during the cutting operation. When using these same small instruments, it was determined that either the water-air spray or the water stream serves as an efficient coolant. Little significant difference was experienced when using mild room temperature water or mouth temperature water." There is no question but that the control of temperature during the cutting of tooth structure is of utmost importance. I can, for instance, visualize a scene that occurred when I took my first pair of ice skates to be sharpened. With the skate held against a revolving carborundum wheel, a shower of sparks was immediately produced. I would need no better example of what frictional heat can do. I am sure the need for using an efficient method of controlling the temperatures developed during the cutting of tooth structure is obvious to all of us.

PRESSURE

When we examine the research performed by investigators during the past fifteen to twenty years, we became cognizant of the fact that many refer to pressure in terms of pounds in cutting tooth structure, in some instances as much as four pounds and more, while today we speak in terms of ounces. I think herein lies one of the great advantages of our ultra high-speed instruments. It is the ability to remove tooth structure with such light pressure that we have extreme control of the instrument, never having to force it. It is significant that when a review of the literature of the tooth-cutting techniques in effect today is made, namely, the airbrasive, the ultrasonic, the turbine type instruments, both water- and air-driven, and our ultra high-speed belt-driven handpieces, they all seem to have two things in common—namely, the ability to cut with light pressure and absence of vibration.

In 1954, Peyton and Henry[16] stated: "It has been observed clinically that the normal reaction of an operator to an increased speed of operation for any given instrument is to use a lighter pressure on the handpiece." Any of us who are using the ultra high-speed instruments can agree with this. A technique for using the cutting tool as if using a fine camel's hair brush and a light intermittent cutting stroke is soon developed. The light touch results in ease of control with the practical elimination of the grinding tool creeping or jumping. This characteristic is one of the chief advantages of these high-speed instruments.

VIBRATION

One of the most disturbing factors in cutting tooth structure is the vibration that is experienced by the patient. When vibration is accompanied by pressure, the apprehension of the patient is naturally increased. The elimination of these two objections through the use of high-speed techniques makes it more than worth while. Make no mistake about it, the difficulty of operating is tremendously increased when the patient is apprehensive. The tension of the patient is immediately sensed by the dentist, resulting in fatigue and discomfort for both.

As we increase our operating speeds, we lessen the intensity of vibration perception. The problem of vibration is not related to the cutting tool alone. The type of handpiece used, the condition of the belt, and the type of pulleys used all can have a bearing on the amount of vibration that is set up which, in turn, is transmitted to the tooth.

Within recent years, a number of instruments and methods have been introduced to the profession, all aimed at the reduction of the unpleasantness brought about by vibration and heat in cutting tooth structure. It would appear that we have come a long way toward the solution of these problems. New instruments are appearing on the market, some of which have not been in use long enough to be evaluated. We are living so close to the subject that I do not think we fully appreciate some of the changes that are taking place along the lines of operative procedures involving the cutting of tooth tissue. Great credit should go to those who have devoted so much time and effort toward the goal of making our dental operations more acceptable to the public. When one works with these new instruments, the thought keeps reoccurring that here, at last, we are approaching a point where patients no longer need view with dismay the necessity of having tooth cutting preparations made in teeth. There is no great question about the fact that increased speed results in much greater efficiency in removing tooth structure without vibration.

INTRODUCTION OF THE FIRST BELT-DRIVEN HANDPIECE

In 1955, McEwen described the high-speed handpiece developed by Dr. Richard Page. McEwen spoke of using, clinically, speeds in the 160,000 r.p.m. range, and this stimulated my interest in what is termed "ultra high speed" instruments. Up to this time, I had been using speeds of around 15,000 to 20,000 r.p.m. Needless to say, the concept of using what seemed to be fantastic speeds was not too easy to accept at first. I must confess that I approached the change with a certain amount of misgiving. After first trying this instrument on extracted teeth, my reaction was one of surprise when I discovered that the cutting tool was under complete control and that it had no tendency to run or jump. The feeling was one of simply guiding and directing the application of the cutting tool. This instrument, marketed as the Page-Chayes handpiece, was a complete departure from all previous ideas in design of tooth-cutting devices. It was belt-driven and completely eliminated the necessity of using gears. Lubrication was built into the bearings. McEwen stated that the advent of high speeds was as important a step forward as the change from the foot engine to the electric engine. In 1957, Kilpatrick[18] stated, "The problem to be solved by many dental practitioners is not whether he should use higher rotational speeds, but what equipment at what speeds will benefit him and his practice the most." He further states that "there is no significant advantage in going from 26,000 R.P.M. to 45,000 R.P.M., as the cutting advantage will be so slight . . . When we jump from 45,000 R.P.M. to 100,000 or above there is a very spectacular increased cutting efficiency." A number of manufacturers have since entered this field with

belt-driven instruments; among them are the Surgident Company, the Kerr Company, and the Mid-West Company.

ADVANTAGES AND DISADVANTAGES

I think all of these new instruments have certain advantages and certain disadvantages. I believe that the advantages far outweigh any disadvantages. One great advantage in using the Page-Chayes type is the decrease in the necessity of using disks in the mouth. The ease with which an old bridge can be removed using carbide fissure burs make it invaluable. The practical elimination of vibration and pressure, in using this instrument, would be justification enough for its use if used for no other reason. The life of cutting tools is increased, and their cutting efficiency is higher. No handpiece lubrication care is required. I prefer to put finishing touches to my intracoronal type of preparations with a slow-running type of cutting instrument or to run the Page-Chayes handpiece at a low rate of speed, regulated by the foot control. In either case, we must return to the vibration perception range of cutting, but only for short intervals. Hand instruments still have their place in dentistry and should be used where indicated. The problem of changing from a contra-angle to a straight handpiece, and vice versa, does not involve a change at the wrist joint, but it may be considered a disadvantage by some when first used. While I do not consider the two engine arm setup a necessity, it could very well be the trend, as some manufacturers have them in production. The difficulty of removing tooth structure in an efficient manner in order to make good preparations is one of the stumbling blocks that I feel has been overcome with the use of higher rotational types of equipment. Patient acceptance is good, and it is fortunate that the improvements in our methods of cutting tooth structure have come about at a time when the public demand for esthetic types of dental restorations is on the increase. The difficulty of eliminating axial line angles in ¾ and full coverage preparations has most certainly been solved by these high-speed instruments. Due to the fact that there is no crawling or jumping of the cutting tool, it is a simple matter to round and smooth off these areas that only recently caused us a great deal of difficulty in trying to establish a finishing line or shoulder. McEwen[19] made a very appropriate statement when he said, "For the first time in dentistry the instruments are actually doing the work for which they were designed."

It has been stated[20] that "a considerable variation exists between different brands of carbide burs." This statement serves to point out the necessity of careful checking of the shank sizes of the cutting tools that we are using in high speed and ultra high speed equipment. While it may be possible to develop a tactile sense as a guide when inserting these burs and stones, I have found that it is best to occasionally check the sizes with a micrometer. The ordinary bur shank is 3/32 inch, plus or minus 1/1,000, in diameter. The Page-Chayes type of bur shank is 1/16 inch in diameter. It is equal to 0.0625 to a differential of 0.063. In other words, the ordinary bur specification allows for 1/1,000 of an inch tolerance, whereas the Page-Chayes type bur allows only for one-half of 1/1,000. As you take advantage of the increased cutting efficiency of higher speeds, the degree of precision to which cutting tools are made becomes more and more important.

The engine speed should be checked occasionally. I do this by checking the speed of the straight handpiece with a tachometer. I have a high- and low-speed switch built into the side of my unit. On my low-speed switch I register about 24,000 r.p.m. on the Chayes straight handpiece. This figure is multiplied by 5, which gives 120,000 r.p.m., the approximate speed used with the Page-Chayes contra-angle handpiece. On the high-speed switch, my tachometer reading registers in the neighborhood of 30,000 r.p.m., although it has registered as high as 32,000 r.p.m. The variation is accountable to the degree of belt tension used and other factors, such as lubrication of both the handpiece and pulleys. Figuring my high-speed switch as delivering 30,000 r.p.m. times 5, we have a speed of approximately 150,000 r.p.m. Only short bursts of speed are used in checking with the tachometer.

SUMMARY

When we review the history of the development of tooth-cutting techniques, we can realize how slight our progress was from the introduction of the dental engine in 1871 up to the end of World War II. It is generally accepted that the past 10 to 12 years have resulted in a tremendous interest in devising means that would meet patient acceptance and tolerance to cutting tooth structure. Black's work on the airbrasive concept was the stimulation that was necessary to bring about our realization of the shortcomings of the methods we had been using up to that time. At present, the field of tooth-cutting techniques is still in a rapidly changing state of flux. Up to now, there is no one instrument that has been devised that will meet the requirements of each individual dentist. In the minds of some, the advantages of one instrument are offset by some disadvantage. Those who have been using comparatively low speeds in tooth cutting instrumentation may be reluctant to abandon a technique that has proved satisfactory for many years.

Each dentist must decide for himself, through investigation and use, the type of equipment best suited to the requirements of his practice. None of us can be expected to clutter up our offices in an attempt to use all of the various instruments and techniques that are available today. We would have neither the time nor the space to accommodate such procedures. My attempt throughout this article has been to evaluate and discuss, from practical angles, my own experiences in using certain instruments and any knowledge that I may have gained through published literature. No doubt, considerable time will have elapsed before we can honestly say, this is the instrument that we should use; this is the instrument most acceptable to patients; this is the instrument that stands out above all others, that is superior in its performance to obtain the best results.

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PREVENTIVE TECHNIQUES AS AN ADJUNCT TO OPERATIVE DENTISTRY

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NEW TECHNIQUES AND MATERIALS have improved our ability to treat dental caries with operative procedures. Caries incidence, however, is of such magnitude that only a part of the dental requirements of the population can be met in this way. Without a large increase in the available number of dentists, the problem can be solved *only* through the use of preventive procedures.

During the past fifteen years, there has been considerable research on agents and techniques which might reduce the incidence of dental caries. For the most part, the interest has been in two directions: reducing acid formation at the tooth surface, and increasing the resistance of the tooth to acid attack. Some of the suggested methods have been studied extensively and show considerable promise; others have given indications of merit in preliminary testing, but have not stood up under large-scale clinical evaluation.

Probably the most complete program in the history of dental research has been the work on the relation of water fluoridation to caries. Several 10-year studies have been completed, and there is general agreement that, in a group receiving one part per million of fluoride during the entire period of tooth formation, there is a reduction of 60 per cent in new decay when compared to the control groups.[1,2,3] In children whose teeth had already begun to form at the start of these studies, the reduction was slightly lower. However, even in children who were 8 years old at the start of fluoridation (all crowns except third molars were calcified), there was 30 per cent less decay than in the control group.[4] With the exception of an occasional slight whitish fleck or opaque area in the enamel, no deleterious effects could be noted in the experimental groups. There is no longer any doubt that water fluoridation is a safe, effective preventive procedure.

The dentist interested in preventing dental caries has an obligation to help implement a water fluoridation program in his community. Experience in a number of areas has demonstrated that it is not enough to quote statements in support of fluoridation from various professional bodies and to dismiss opponents as "crackpots." The dentist must familiarize himself fully with the information available and help educate his community.[5,6]

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TOPICAL APPLICATION OF FLUORIDES

In areas where water fluoridation is not being used, topical application procedures for children are indicated. Recent work has shown that stannous fluoride is significantly superior to sodium fluoride in this regard.[7,8] The recommended technique is to give a thorough prophylaxis followed by an application of a 4 per cent freshly prepared aqueous solution of stannous fluoride to the teeth. Three more applications of freshly prepared stannous fluoride should be completed within a 2-week period. These subsequent applications are *not* to be preceded by a dental prophylaxis. The manner of isolation and application is the same as that for sodium fluoride. A modification of the foregoing procedure also has been recommended. This involves the use of a freshly prepared 8 per cent stannous fluoride solution applied once a year following a prophylaxis.[9] It appears that this procedure, too, is more effective than four applications of 2 per cent sodium fluoride.

A number of reservations must be kept in mind when using topical fluoride procedures. Most of the work to date has been done with children up to the age of 15. There is little evidence of effectiveness in older individuals. It is not known whether the stannous fluoride (four application series) is effective after 2 years. At this stage, repetition every 2 years up to the age of 15 years appears to be desirable. Lastly, it should be realized that the reductions in caries incidence reported represent *average* data for large groups of patients. It is impossible to predict what the percentage reduction will be for any one individual. This should be pointed out to the patient in order to avoid any misunderstanding at future examinations when new caries lesions may be disclosed.

SILVER AND ZINC SALTS

There have been a number of conflicting reports on the use of silver and zinc salts applied topically to increase tooth resistance to attack by caries.[10-13] The larger, better controlled studies which have been carried out produced negative results, and it would appear that heavy metal impregnation techniques are of doubtful value in reducing decay.

REDUCTION OF ACID FORMATION

Reduction in acid formation at the tooth surface has been attempted in a number of ways. The most effective method is to deprive the acidogenic flora of a substrate by restricting the carbohydrate intake. In cases of marked caries susceptibility, it is advisable to work with a caries control laboratory which provides diet plans for the patient and checks progress through periodic salivary tests. In cases of moderate susceptibility, dietary counseling alone may be adequate, provided there is good patient cooperation.

During the past few years, we have become more concerned with the form, as well as the amount, of carbohydrate ingested. The Vipeholm Dental Caries Study[14] demonstrated that the amount of caries produced by sugar is related to the tendency of the sugar containing food to be retained on the surface of the teeth. Sugar in solution, for instance, was found to be much less cariogenic than sugar in toffee and chocolates, especially when eaten between meals.

Dietary counseling to reduce caries should include the following recommendations: (1) *moderation* in the use of sugar-sweetened beverages, jams, jellies, syrup, honey, and refined cereal products, (2) *elimination* of tacky chewy candies such as toffee, chocolates, caramels, etc., (3) *elimination* of readily impactable carbohydrates, such as crackers, potato chips, cookies, etc., especially between meals. In general, foods rich in refined carbohydrates, not specifically restricted, should be confined to meals. Many normally cariogenic items are now available with non-sugar sweeteners and should be recommended to the patient.

DENTIFRICES

Another approach to the reduction of acid formation is the incorporation into dentifrices of neutralizing or inhibiting agents. These include ammonium salts, urea, chlorophyll, penicillin, sodium N-lauroyl sarcosinate (antienzyme), and fluoride salts.

The advent of ammoniated dentifrices ushered in an era of widely publicized allegations that so-called "miracle ingredients" could prevent decay. Most of the advertising claims were based on preliminary laboratory tests, and the products were sold long before the results of clinical tests became available. It is important for dental practitioners to be conversant with the literature on medicated dentifrices in order to recommend only those products that have been subjected to well-controlled, independent investigation.

The so-called ammoniated dentifrices can be divided into two general types: (1) in which the principal agent is 5 per cent dibasic ammonium phosphate (usually accompanied by 3 per cent urea); and (2) in which the principal agent is 12-22.5 per cent urea (and may contain up to 5 per cent dibasic ammonium phosphate as well).

Several studies with dentifrices containing dibasic ammonium phosphate and low concentrations of urea indicated little or no ability to reduce caries incidence.[15,16] With the high urea preparations, the early clinical reports indicated a reduction in new decay of 40-60 per cent.[17,18] In a more recent, better controlled study, supervised brushing with a toothpaste containing 13 per cent urea and 5 per cent dibasic ammonium phosphate was found to reduce new decay only 25 per cent.[19]

With regard to chlorophyll-containing dentifrices, in March, 1949, the Council on Dental Therapeutics stated, "Therapeutic claims are not substantiated by sufficient controlled clinical evidence to justify their acceptance even for clinical trial." There have been no reports in the literature, since 1949, to justify any modification of this position.

In view of the effectiveness of penicillin against many acidogenic organisms, it seemed logical to investigate the efficacy of this antibiotic in the prevention of dental caries. The results of clinical studies appear to be conflicting. Zander, in 1950,[20] reported a reduction of 54 per cent in new decay with a tooth powder containing 500 units of penicillin per gram. Four other groups of investigators found little or no reduction.[21-24] In view of the preponderance of negative clinical findings, as well as the possibility of developing penicillin-resistant forms of oral microorganisms,[25] a penicillin dentifrice can hardly be recommended.

In the two clinical studies reported to date, a dentifrice containing 2 per cent sodium N-lauroyl sarcosinate (antienxyme) was found to reduce decay 57 per cent over a 1-year period[26] and 47 per cent over a 2-year period.[27] If these results can be confirmed by independent investigation, the antienzyme dentifrice could be an important adjunct in reducing caries incidence. Its recommendation at this time, however, is premature.

A dentifrice containing sodium fluoride was first tested for effectiveness against caries in 1945.[28] The result was completely negative. More recent investigations have confirmed this lack of effectiveness.[29,30]

The superiority of stannous fluoride over sodium fluoride in experimental rat caries[31] and in topical application procedures[7] suggested its incorporation into a dentifrice. A number of articles have appeared on the efficacy of a dentifrice containing 0.4 per cent stannous fluoride (1.0 mg. fluoride and 3.0 per cent mg. tin per gram of dentifrice) as the active agent and heat-treated calcium orthophosphate as the abrasive. The earlier articles indicated 50 per cent effectiveness in reducing new caries.[32,33] More recent articles have indicated a reduction in the neighborhood of 35 per cent.[34,35] One possibility for the reduced effectiveness in the later studies may be the loss of activity of the stannous fluoride on standing. An improved formulation has been claimed.[35] Enough evidence has been accumulated to warrant a cautious recommendation for the use of stannous fluoride dentifrices as a means of achieving a moderate reduction in the incidence of caries.

In recommending dentifrices, it should be borne in mind that a study, in 1950, indicated that brushing directly after meals reduced caries over 50 per cent when compared with indiscriminate oral hygiene procedures.[36] The test dentifrice was essentially calcium phosphate and a detergent—the basic ingredients of most dentifrices.

OTHER METHODS

With the realization that tooth form and position may enhance carbohydrate retention, stagnation, and subsequent conversion to acid, the practicing dentist has an additional method at his disposal to help prevent further decay. Adjustments of marginal ridge height of contiguous teeth, closing open contacts, and correction of local occlusal disharmonies may reduce the incidence of decay as well as prevent periodontal involvement. Also, it has been suggested that pre-carious pits and fissures of posterior teeth be excavated and restored with amalgam or gold fillings. Early placement of small fillings in these areas (prophylactic odontotomy) may well prevent the necessity for larger restorations at a later age and, in many instances, may even prevent the loss of teeth. Although this is a restorative procedure in itself, the high attack rate of occlusal areas and the high mortality of first and second molars make prophylactic odontotomy, from this point of view at least, a preventive measure.

SUMMARY

It is apparent that, although the goal of preventing dental decay is far from realization, means of reducing decay are available. Water fluoridation, topical ap-

plication of fluorides, carbohydrate reduction, urea and stannous fluoride-containing dentifrices, tooth brushing directly after meals, correction of local factors which enhance food retention, and prophylactic odontotomy all possess some value in decreasing the incidence of new caries. Thanks to continued research, our armamentarium is growing.

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MEASUREMENT OF THERMAL EXPANSION OF CRISTOBALITE TYPE INVESTMENTS IN THE INLAY RING—PRELIMINARY REPORT

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MEASUREMENT OF THE THERMAL expansion of investment has generally been concerned with the unrestricted expansion of a cylindrical specimen.[1] Although such data provides valuable information in regard to the basic behavior of the investment, the expansion occurring in the restricted confines of the inlay ring, and the effect of such expansion on the actual size of the mold, may be quite different from that which takes place in an unrestricted specimen. It is possible that some of the unexplained variations occurring in established casting procedures are attributable to a lack of knowledge in this area. Therefore, the purpose of this investigation was to establish a test method for measuring the thermal expansion in the inlay ring and to secure data relative to the influence of certain variables on such expansion. This article must be considered only as a progress report.

METHOD

Inlay patterns were formed on a stainless steel, MOD die similar to that advocated by the Bureau of Standards. The patterns were sprued and placed in a specially prepared inlay ring. The ring had two small slits cut on each side of the ring, extending approximately two-thirds the length of the ring.

Annealed stainless steel, T-shaped wires, 0.016 inches in diameter, were imbedded in the pattern. One end of the T engaged the pattern while the other end was imbedded in the investment (Fig. 1). Reference marks were filed on the opposite ends of the wires for measurement with a comparator microscope. The ends of the wires extended through the liner and the slits in the inlay ring. The distance between the reference marks was approximately 90 mm. After the wires were imbedded, the pattern was stored off of the die for 4 hours at room temperature in order to relieve, as much as possible, the residual stress.

A solid piece of annealed stainless steel wire, the same length as the imbedded T wires, was placed through the ring in a position approximately 5 mm. above the pattern. This wire served as the control in calculating the thermal expansion of the wires imbedded in the pattern itself.

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At the points where they passed through the inlay ring wall, the wires were supported by porcelain tubing having an internal diameter of 0.025 inches. All portions of the wires which were inside the ring, except the short arms of the T, were lightly coated with petroleum jelly and the space between the wires and the porcelain tubes was also filled with petroleum jelly. This lubricant prevented the wires from adhering to the investment and proved to be the most satisfactory of several tried. Investment was then poured into the ring, and a chromel-alumel thermocouple inserted close to the pattern. After the investment had set, the fiducial readings on the wires inserted in the pattern and the control solid wire were taken.

The inlay ring and wires were now placed in a small muffle furnace which also had slits in the side to permit the wires to protrude. The microscope was mounted so that the objective was in the same focal plane as the wires. The specimens were heated to 450° C. and held for 30 minutes before measurements were taken.

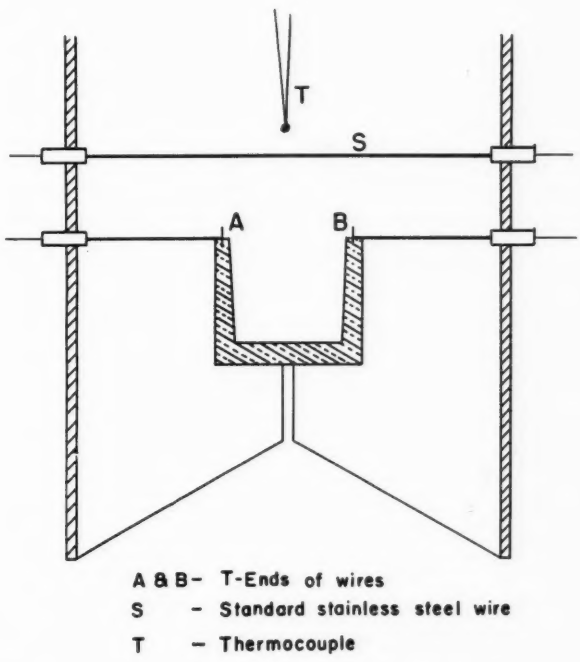

Fig. 1.—Diagram of the specially prepared test inlay ring.

The following method was followed in calculating the thermal expansion. It was presumed that the ring was maintained at an even temperature throughout its bulk. The distance between the inside ends of the T-shaped wires was measured. A value for the thermal expansion, between room temperature and 450° C., of a wire of this length was calculated from the thermal coefficient of the wire. This figure was subtracted from the experimentally determined expansion of the control wire. That value thus represented the thermal expansion of the wires which were

imbedded in the pattern. The measurements taken were then corrected for this thermal expansion of the wire itself.

Patterns were invested in two areas of the ring, 4 mm. from the open end and 4 mm. from the crucible former. Tests were made using both one and two layers of asbestos lining, 0.75 mm. thick. The investment used was Kerr's Cristobalite and Cristobalite with control powder at a 50:50 ratio. The thermal expansion was determined with the wires imbedded at the gingival floors (as diagrammed) and also placed in the area of the axiopulpal line angles. A minimum of four specimens was measured in each series and the mean values are presented here. The results were quite reproducible, standard deviation being 0.05 per cent which is comparable to the conventional quartz tube method.

TABLE I. INVESTMENT-CRISTOBALITE (WATER-POWDER RATIO 20:50)

POSITION MEASURED	SPRUE LENGTH	NUMBER OF LINERS	EXPANSION (PER CENT)
Axiopulpal line angles	long	1	1.4
"	short	1	1.4
"	long	2	1.4
"	short	2	1.4
gingival	long	1	0.5
"	short	1	0.5
"	long	2	1.0
"	short	2	1.1

TABLE II. INVESTMENT-CRISTOBALITE (RATIO 50:50)

POSITION MEASURED	NUMBER OF LINERS	EXPANSION (PER CENT)
Axiopulpal line angle	1	0.7
gingival	1	0.5
"	2	0.7

RESULTS

No difference could be detected between a short or long sprue in either of the dimensions measured (Table I). The thickness of the asbestos liner markedly influenced the gingival expansion but not the expansion at the pulpal floor. When the technique of applying the liner was standardized, little variation occurred in specimens where the same thickness of asbestos liner was used. However, if the liner was not in contact with the ring, the values for the gingival expansion with a single liner varied even more than the maximum found for two liners.

Control powder, at the ratio used, reduced the expansion in the area of the pulpal floor (Table II). The expansion was approximately the same as that determined by the quartz tube method. In the gingival area, the expansion was somewhat less with a single liner. These measurements agree again with the thermal expansion values obtained using the quartz tube method.

DISCUSSION

It has been shown previously[2] that the position of the pattern in the ring markedly influences the amount of compensation obtained during setting expansion. The compensation varies little in the axiopulpal line angle area of the pattern, but the gingival expansion does increase as the pattern is placed closer to the crucible former. Further research has indicated little change in either dimension with use of a thinner wax pattern or by use of two liners. On the basis of the data obtained

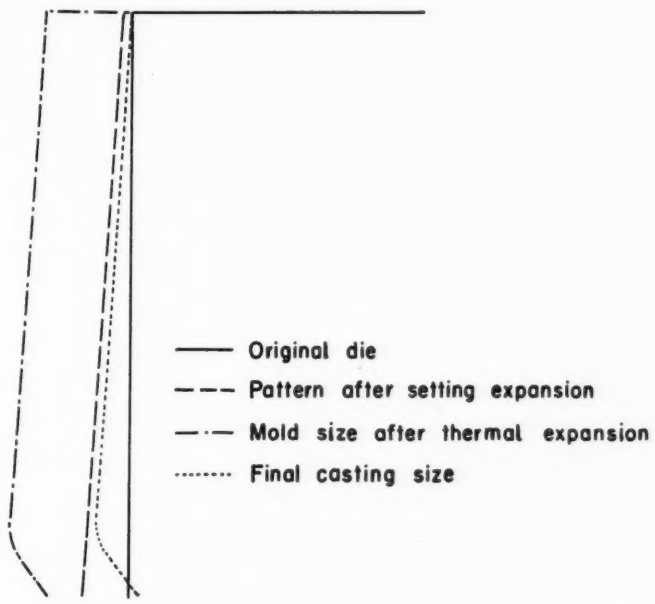

Fig. 2.—The types of changes occurring in the casting procedures. Schematic drawing through the center of the proximal wall of an MOD inlay.

in these investigations, the following calculations might be made in regard to the dimensional change which occurs with a Cristobalite-type investment during the casting process.

Single liner		*Occlusal*	*Gingival*
Setting expansion		0.0%	+0.8%
Thermal expansion		+1.4%	+0.5%
	TOTAL	+1.4%	+1.3%
Double liner			
Setting expansion		0.0%	+0.8%
Thermal expansion		+1.4%	+1.0%
	TOTAL	+1.4%	+1.8%

Regardless of whether a value of 1.25 per cent[3] or 1.5 per cent[4] is used for the contraction of the gold alloy, no casting would be an exact reproduction of the wax pattern. Just arbitrarily using 1.5 per cent as a value for the contraction of a gold alloy, the various changes which might occur are schematically shown in Fig. 2. If other values were employed for gold contraction, the size of the final casting would, of course, vary, but the purpose of this figure is merely to show the general types of changes which occur. Although the occlusal or extreme gingival dimensions of the casting are quite accurate, a distortion has taken place in the proximal area. This effect can readily be demonstrated when a snugly fitting casting is placed on a steel die of a slight taper. Marks showing where binding occurs can be seen along the gingivoaxial margin. This binding is dependent on the degree of setting expansion obtained and the influence of the asbestos liner.

No attempt should be made at this time to correlate these data with practical dental castings. The exact significance of the results is now under investigation.

CONCLUSIONS AND SUMMARY

A technique has been presented for measuring the thermal expansion of investments in the inlay ring. The thermal expansion of the investment is restricted by the inlay ring and with a single asbestos liner, the expansion of a Cristobalite investment is in the magnitude of only 0.5 per cent in certain areas. However, in those parts of the mold not directly connected to the ring walls by a continuous mass of investment, the expansion is much greater. The position of the pattern in the ring has no effect on the thermal expansion, and the use of a quartz control powder influences only the areas in the investment which can expand freely.

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RESEARCH

A CRITICAL ANALYSIS OF THE BENNETT MOVEMENT. PART II

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STUDIES BY THE OPTICAL METHOD

Seven out of the eight illustrations exhibited in Bennett's essay[1] have for their objective the demonstration of the validity of his concept of a constantly shifting center of rotation with movements of the mandible only in a vertical plane. The major part of the discussion in his article centers around the purely geometrical and mechanical theory of the center of rotation, reinforced by the optical method of "reproducing" mandibular movements in a vertical plane only.

It must be noted that Bennett conducted the experiments exclusively upon himself, and the optical method itself is subject to a careful examination, with a view to determining its validity as a final yardstick for measuring biologic values of condylar movements.

Bennett stated that, on account of the loss of his lower molar teeth on each side, it was possible for him to attach his optical apparatus to his bicuspid teeth without having any interference from wires crossing occlusally. Because of the lack of his lower molar teeth and the pathologic patterns of occlusion that would be expected to accompany such severe conditions of deterioration of the masticatory apparatus, Bennett should have disqualified himself as a subject for this type of experimentation. His masticatory stroke could have deteriorated, as a result of his dental infirmity, into a lateral occlusion associated with an *excessive protrusive* mandibular movement. Furthermore, Bennett's "pseudo" lower partial denture may not have possessed adequate stability to carry the outside wire framework rigidly with the glow lamps as an integral part of the mandible.

In another part of his essay, in discussing his Fig. 8,[1] he stated, "When obtaining this diagram I was sitting facing the wall in order to show any lateral movements of the right condyle. The line A, which is nearly vertical, is produced by extreme opening without lateral movement. You will notice that it deviates slightly to the right; this is somewhat interesting because I am slightly larger throughout on the right side, and apparently the want of symmetry exists also in mandibular movement."

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Is not Bennett's own description of his physique a valid reason to disqualify Bennett as a subject for such delicate experiments? Furthermore, temporomandibular joint syndromes, in which the opening component is associated with a deviation of the mandible laterally, are considered most frequently to be syndromes of a chronic type. They may or may not be associated with pain, and they are usually the result of abnormal occlusions with evidence of tooth migration of many years' duration. Bennett's description of his own mouth suggests this type of abnormal occlusion, and yet it was the only one used in the experiment.

Bennett had "an outside framework of wire with a side piece in a vertical plane parallel to the median plane and just outside the right condyle. Two very small incandescent glow lamps were then attached, one immediately opposite the condyle and one opposite the sulcus below the lower lip."[1] This outside framework was firmly attached to the pseudo lower partial denture in his mouth. He claimed that the little glow lamp that was attached to the outside wire framework opposite the "centre" of his right condyle was registering accurately the physiologic movements of his condyle when the mandible performed various movements.

It is difficult to agree with this statement. Bennett could not have placed the glow lamp against his skin opposite the right condyle because he used this same side, in his experiments, as a balancing side with the condyle moving downward, forward, and *medially.* If the glow lamp was placed originally against the skin opposite the "centre" of the condyle, and if we assume that it would follow the path of the condyle *medially,* then the pressure and friction of the lamp against the skin of his face would have precluded its accurate use. Therefore, it was necessary to keep the lamp *some distance away* from the soft tissues opposite the condyle. It is unlikely that Bennett could have placed the glow lamp on the lateral pole of the condyle in direct continuation of its oblique axis where it really belonged. Such precision work could not be achieved in those days without being guided by good roentgenographic records which were lacking. The glow lamp could not possibly have been placed in the same anteroposterior position with the same peculiar anterior bend as is manifested by the condyle. *Most important is the fact that the outside wire framework and, with it, the glow lamp were attached to Bennett's bicuspid and anterior teeth only.* (His molar teeth were missing on both sides.) Therefore, any movement of the glow lamp was dependent upon the occlusal guidance and the changed inclinations of his remaining anterior teeth, but it would not represent the true physiologic condylar movement. With such abnormal tooth guidance, we should expect the movements of the glow lamp outward and downward to be considerably magnified. In a general way, the Bennett optical method of investigation of mandibular movements is inadequate as a scientific method of research, even on individuals with normal occlusions. If the condyle and the glenoid cavity were in continuous bone-to-bone contact (as the mandibular and maxillary teeth are when they glide one upon another), our problems in this field would be considerably facilitated. However, since the mandible is suspended from the cranium by means of the capsular ligament, the individual condyles may move in directions opposite to those in which other parts of the mandible move. This is precisely the case with the condyle on the working side, and it occurs under

the influence of a resultant force representing the sum total of all the muscular forces that tend to rotate the mandible into a lateral working position. Bennett's Fig. 8[1] illustrates extreme lateral mandibular movements with the teeth in continuous contact and in extreme opening components associated with extreme lateral movements.

About the *extreme lateral mandibular movements* Bennett has this to say, "These two movements represent as nearly as possible those of normal mastication."[1] This statement can be seriously questioned. With the teeth in continuous contact in normal mastication, lateral movements do not go out farther laterally on the working side than to effect contact between the buccal cusps of the mandibular teeth with the buccal cusps of the maxillary teeth.

Bennett's Fig. 8[1] poses another question: Why should C′ represent an *extreme* lateral mandibular movement with the teeth in contact, and why should B′ represent an *extreme* lateral mandibular movement associated with an *extreme* opening component? The word "extreme" implies strained, abnormal relations. Why not use average normal movements that are physiologic in nature?

According to Bennett, in the instance of C′, the mandible moves to the right and slightly downward. For the mandible to move "slightly" downward and laterally with the teeth in continuous contact implies a movement downward corresponding at least with the cusp height of the teeth. Such a downward movement of the condyle, with the teeth in continuous contact, implies also a movement of the mandible forward in accordance with the mesiodistal inclined planes of the teeth. Therefore, the lateral mandibular movement C′ is three-dimensional (laterally, downward, and forward). The same is true in the instance of C which is the balancing side. The condyle movement associated with this occlusion is downward, forward, and medially (three-dimensional). These three-dimensional movements of the condyle cannot be registered by a glow lamp with a single line on a flat wall. An additional screen should have been placed on the ceiling, and biconvex lenses, specially arranged for projection of the light from the glow lamp upward, should have been used. But even then this optical method of registering the mandibular movements would not reproduce the dynamic physiology of the condylar movements.

Bennett's experiments on lateral mandibular movement were confined to *extreme* lateral mandibular movements with the teeth in continuous contact and to *extreme* lateral mandibular movements with the jaws wide open. Such extreme mandibular movements are severely strained and create tremors in the muscles producing them. This, in turn, makes it impossible to pin point these extreme mandibular positions and relations (Figs. 21, 22, and 23).* With an extreme jaw opening component, it is impossible to perform a lateral mandibular movement since the same external pterygoid muscle serves for extreme opening and for lateral movement, and this muscle cannot engage in these two basic extreme functions at the same time. On the other hand, when the mandible is in an extreme lateral relation, normal jaw opening is interfered with for very similar reasons.

*Figure numbers in this article are continued from Part I which appeared in the July, 1958, issue of the JOURNAL.

Fig. 21.—An electrified skull, with the glow lamps lit, was used in experimentation for projection of the images of the glow lamps upon the screen. Projection was done when the biconvex lens and the screen were close together and far away from the skull.

Fig. 22.—The wire framework, with the corresponding glow lamps, is rigidly attached to the mandibular teeth with no occlusal interference. The wire framework is attached to the teeth by means of orthodontic steel wire at and below the cemento-enamel junction. The subject for these experiments has what prosthodontists call a balanced occlusion. However, the projection and the precision pin pointing of the images associated with various extreme mandibular movements are extremely difficult, if not impossible.

The masticatory mechanism with all its adjacent and associated structures constitutes, both structurally and functionally, one of the most complex areas of the human organism. In addition to mastication, it is an essential factor in deglutition, speech production, and respiration. In all of these functions, there is participation by the mandible. The complex function of the masticatory mechanism is a result of the dynamic equilibrium and synergistic action of various muscle groups. Mandibular movements in mastication are the result of a multiplicity of highly coordinated and reciprocally innervated reflexes in which the muscles of mastication, the suprahyoid and the infrahyoid muscle groups, are all in a remarkably delicate state of balance, synergy, and synchronization. Bennett had no intention to offer a new status for lateral mandibular movements. The dental profession has misunderstood the main objective of his famous paper of 1908.

Fig. 23.—Successful projection of the images of three glow lamps upon the screen with the teeth of the skull in centric occlusion is recorded. Great difficulty is encountered with the projection of the same images for strained lateral mandibular movements and with pin pointing them, respectively.

Bennett's major contribution to dentistry consists in calling our attention to the important fact that no single fixed center of rotation exists for the ordinary movements of opening and closing of the mandible. Also, that *any* opening component of the mandible is always a combination of rotation and translation. He manifested in this area a wealth of intuitive knowledge and a profound understanding of dental problems that perplex our profession even today. That is why Bennett's name will always be synonymous with a true and great leader in the history of dentistry.

ANALYSIS OF THE ILLUSTRATIONS IN THE BENNETT ARTICLE

The Reuleaux[2] method, which was developed in 1875, was used to analyze the mandibular movements. The method defines rotations in a plane in terms of instantaneous centers of rotation (Fig. 24). It has been applied to the study of the movements of the mandible by Chissin[3] and Bennett[1] in living subjects and to the study of the movements of the knee in the living by Zuppinger.[4] Dempster[5] reviewed this theory in relation to the anthropometry of body action.

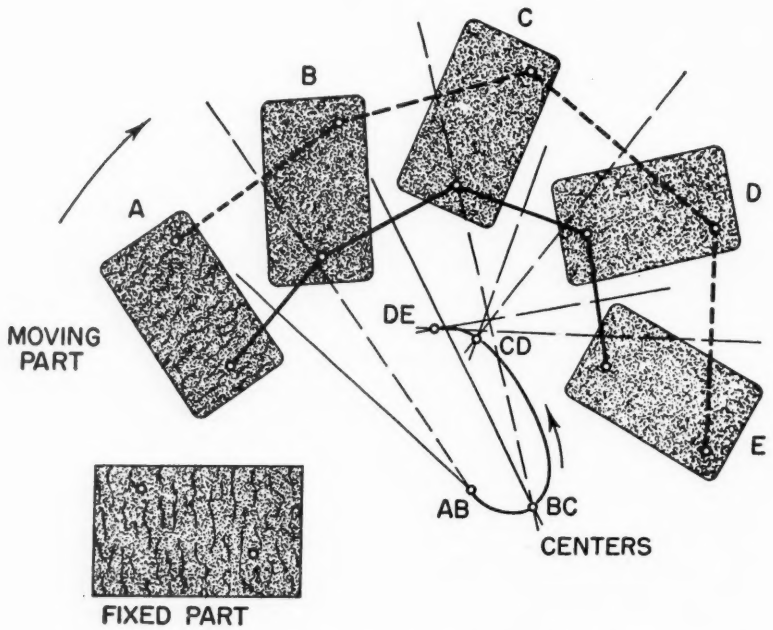


Fig. 24.—Reuleaux method of locating instantaneous centers of rotation. Two points in a body change their angular position as the body rotates from position *A* to position *B*. Lines drawn between the two points of the body in its first position to the two points of the body in its second position are represented by an interrupted and solid line, respectively. Perpendiculars erected from the mid-points of each line meet at point *AB*. This point is the instantaneous center of rotation as the points in the body change their angular positions. Points *BC, CD,* and *DE* represent the individual instantaneous centers of rotation of the body as it progresses from *A* to *E*.

The Reuleaux method represents an accurate picture of movements in a plane. This means that when the head with its rigidly attached glenoid cavity is fixed, any two points on the moving mandible will change their angular relations in the same manner as the moving points on Fig. 24.

Bennett's Figure 1.—This is a discussion of the geometrical and mechanical theory of the center of rotation. To illustrate it, two sheets of paper are placed one upon the other, with the bottom one fixed in position and the top sheet freely movable. On the top sheet, the points A and B are marked and connected by means of a line. Similar marks are made on the underlying sheet so that AB on the movable sheet is coincident with AB of the fixed sheet. The top sheet is slid along, stopping a number of times to record the relations that AB of the top

sheet have with relation to the bottom sheet. A line of the length of AB in seven positions is thus recorded on the fixed sheet (Fig. 25). Seven such positions were recorded in Bennett's Fig. 1.

To formulate a method of reproducing exactly the motion of the top movable sheet, the lines of the bottom sheet are labeled successively as AB, A′B′, A″B″, etc. A and A′ and B and B′ are connected, and perpendicular lines are drawn to the middle point of AA′ and to the middle point of BB′. These two perpendicular lines will meet at a point O. It is seen that AB equals A′B′, OA equals OA′, and

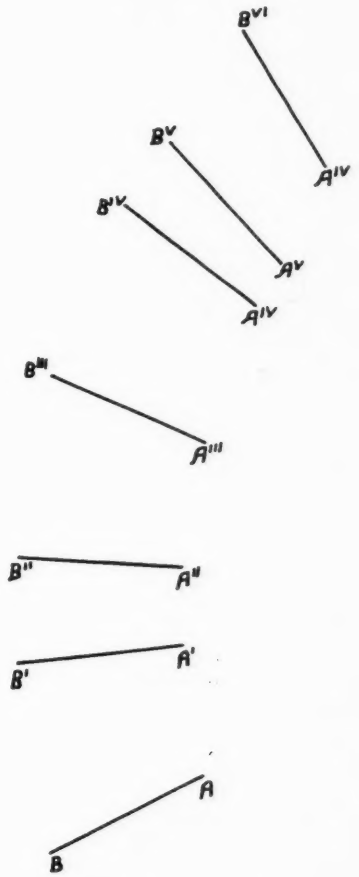
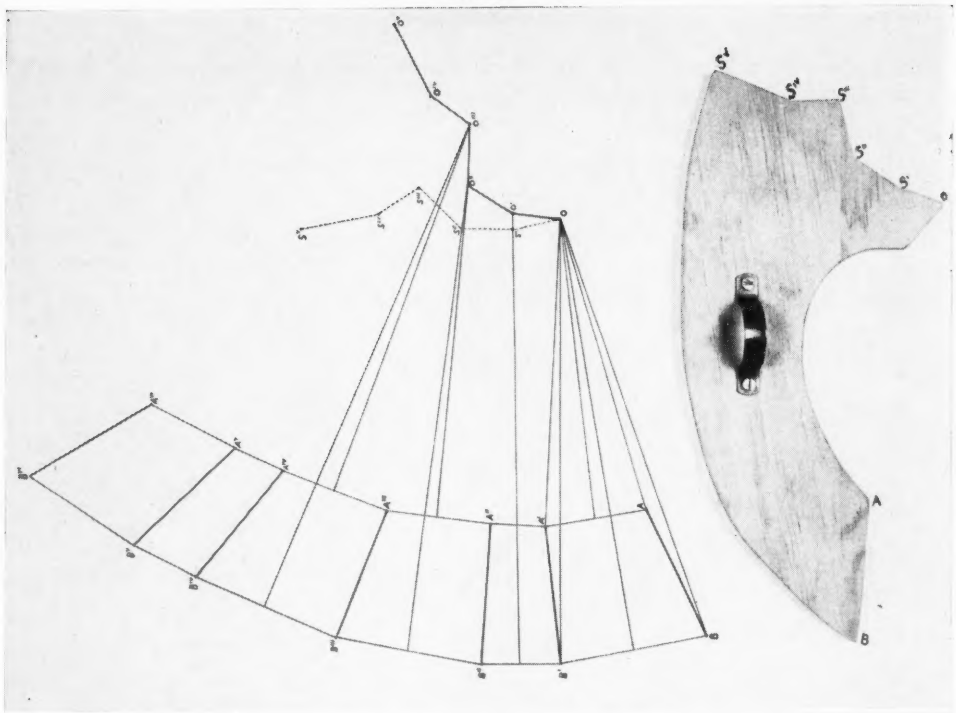


Fig. 25.—Seven successive positions of AB of the top movable sheet are recorded by sliding the top sheet upon the fixed bottom sheet.

OB equals OB′. Hence triangle OAB and triangle OA′B′ are congruent, and triangle OAB can be rotated about point O until it coincides with triangle OA′B′. Therefore, O is an instantaneous center of rotation, about which AB was rotated to come into the position A′B′. Thus, if the top sheet is placed with AB coincident with AB of the bottom sheet, and if a pin was placed through the top sheet at point O of the bottom sheet, the top sheet could be rotated about the pin as the center of rotation so that AB would become coincident with A′B′.

Fig. 26.



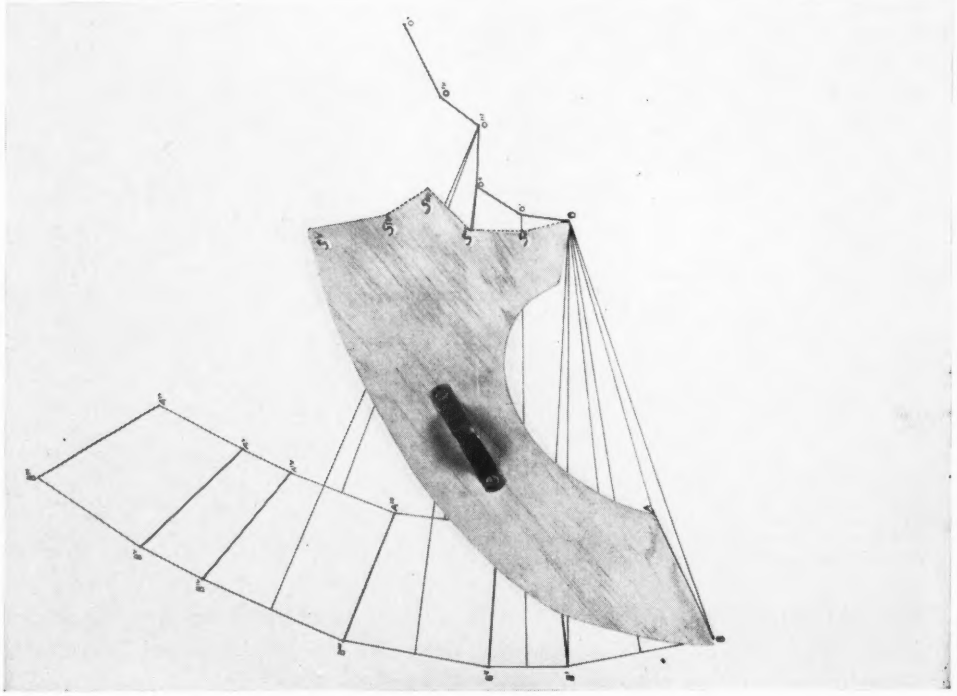


Fig. 27.

Fig. 26.—Bennett's Fig. 1 is reconstructed on the left side and to the right is a wooden model (movable polygon) with a metal handle. This model was constructed in such a manner that the edges along the top side form the polygon O, S′, S″, S‴, S′ᵛ, Sᵛ. The base is formed by the line *AB* and a line connecting points *A* and *O*. The model is used to demonstrate the rolling of one polygon upon another.

Fig. 27.—The wooden model has been placed on Bennett's Fig. 1 and moved to a different position.

On the bottom sheet A′, A″, A‴, etc., are connected, and B′, B″, B‴, etc., are connected, and then perpendicular lines are constructed to the mid-points of each of the lines drawn. Each pair of these perpendicular lines will meet at a point, and points O′, O″, and O‴, etc., result. Bennett omitted most of the lines of construction of the other similar triangles after the first set of triangles had established the validity of his geometrical statement. Thus, the diagram is easier to read.

The points O, O′, O″, O‴, etc., on the bottom sheet form a series of centers of rotation about which AB (or the top sheet) moves. Bennett states, "Next from point O draw OS′ equal OO′ and inclined to it at an angle equal to the inclination of AB to A′B′, that is to say, the angle through which AB moves about O. From S′ draw S′ S″ equal to O′ O″ and inclined to it at an angle equal to the inclination of AB to A″B″, and so on to the last position."[1]

To illustrate reproduction of motion more clearly, a wooden model was cut so that one edge forms the irregular line O, S′, S″, S‴, etc., and the bottom of the model is formed by AB and a line connecting A and O. The other sides of the model can be cut in any manner to complete the polygon (Fig. 26). The wooden model is placed on top of Bennett's Fig. 1 in such a manner that AB and O are respectively coincident with AB and O of the Bennett illustration (Fig. 27). The model is rotated about O, and when OS′ becomes coincident with OO′, AB will be seen to be coincident with A′B′, and S′ and O′ are coincident. Using this point as the new center of rotation, we rotate the movable polygon about O′, being sure to keep S′ coincident with O′, until S′S″ becomes coincident with O′O″. Line AB of the movable polygon now will be coincident with line A″ B″ of Bennett's Fig. 1. This process can be repeated until all such points and positions have been covered.

The positions taken by AB have been considered at rather wide intervals. If the positions of AB were closer together, then the centers of rotation would be closer together and many such centers of rotation would form a smooth continuous curve instead of an irregular line. Thus, one smooth continuous curve could be rotated upon another smooth continuous curve. Hence, Bennett's statement,[1] "Any form of continuous plane motion may be represented or reproduced by the rolling of one curve upon another," is correct. The point at which the two curves contact each other is called the instantaneous center of rotation. Thus, the first instantaneous center of rotation is at O (Fig. 27). The curves themselves would be called centrodes. Bennett shows the specific application of these geometrical considerations in his subsequent illustrations.

Bennett's Figure 2.—Bennett states, "Fig. 2 represents the paths of the condyle and symphysis in normal opening and closing . . . "[1] In these movements, the simultaneous position of the condyle and symphysis have both been recorded. The total movement of the condyle, according to the scale of the diagram, is approximately 11.5 mm. The corresponding total movement for the symphysis is approximately 23.3 mm. This means that 23.3 mm. is the distance that the mandible opens, "in normal opening and closing."[1]

According to the legend for Fig. 2, "The upper curved line represents the path of the condyle and the lower curved line the path of the symphysis during the normal movement of opening and closing. The crosses represent extreme positions of the symphysis."[1] Thus, the path for the extreme movements of the symphysis may be connected by a smooth curve through all of the crosses. "The oval curve which might be drawn through these positions of the symphysis [by connecting the crosses] shows the movement of the mandible obtained by first pushing it forward as far as possible with the teeth in occlusion, and then bringing it downwards, then backwards to the extreme limit, and finally upwards and a little forward to reach the position of normal occlusion. The oval curve, therefore, includes within its area all possible positions of the symphysis."[1]

The points on the diagram which are numbered (1, 2, 3, 4) represent the normal opening and closing movements. The points which are marked with crosses and the letters (A,B,C,D,E,F) are the points representing the position of the symphysis when the mandible is at its extreme strained boundary positions. Bennett shows the areas of greatest and smallest mandibular translation at various degrees of jaw separation and in a state of extreme protrusion and retrusion of the mandible. Measurements of such strained mandibular positions are not reliable, nor can they be pinpointed on the screen with accuracy. Whether the second set of measurements was superimposed over the first so that the paths of the condyle would coincide, or whether they were made with the subject keeping his head in the same relative position and simply making the opening and closing movements is not stated.

Another difficulty arises as to how the pin pointing of the light images on the wall were made with the mandible in an extreme state of tension. This pin pointing of images could be done now with some degree of accuracy by the use of motion picture records, provided the images of the bulbs could be focused with sufficient clarity. Then the film could be stopped at any place and the two points could be registered more accurately.

Bennett's Figure 3.—In this figure, the principle of Fig. 1 is applied to the experimental data as seen in Fig. 2. The line joining similar points of the condyle and symphysis in Fig. 3 may be considered to be similar to AB in Fig. 1. The centrodes seen in Fig. 3 were drawn in the same manner as those in Fig. 1 and are in the form of continuous and interrupted lines, as they were in Fig. 1. As such, if the recordings of the positions of the mandible were accurately made, the centrodes show the instantaneous centers of rotation of the mandible for each particular movement.

Bennett's Figure 4.—Fig. 4 represents a more accurate and more advanced representation of the movement illustrated in Fig. 3. A great number of intermediate points have been placed in their respective correct positions between those already shown on Fig. 3.

Bennett's Figure 5.—Fig. 5 is the path of the condyle shown in large scale. It is taken from an unrelated illustration.

Bennett's Figure 6.—To obtain this illustration, the two glow lamps were placed closer together. One is at the condyle and the one from the symphysis is

placed very close to the condyle. Bennett states, "for the purpose of reproducing the movement of the mandible, the paths of the condyle and of any other point are sufficient."[1] Bennett does not draw the fixed and movable centrodes to show instantaneous centers of rotation, but states, "From these two paths centrodes could be drawn which would perfectly reproduce the movement . . . "[1] This is obvious from the fact that Fig. 1 is a general proof of the proposition that two centrodes can reproduce any form of continuous plane motion.

Bennett's Figure 7.—It is best to consider first the mathematical and mechanical aspects of Fig. 7. Note that the entire link-work mechanism of which Bennett speaks is in one plane. For a preliminary appraisal, QC and QS can be disregarded as these are added to make the link-work mechanism applicable to the dental problem at hand.

The parts that remain are the lines HBQI, QPJ, API, and BA. The link-work itself is made up of three segments which articulate at two points. The segment BQ is part of HBQI. The extension of HB is not important for the present because "the end H is used as a handle to move the link-work."[1] The extension from Q out past I is not important for the moment because it is not needed for the first part of our explanation. The segment of HBQI from Q out past I serves the same function for HBQI that the segment of PI from P out past I serves for API, namely, to serve as extensions for the two lines so that we may see where they intersect. The extension PJ of QPJ is necessary only because, "the jaw J, and the pin P, ensure a smooth movement of the mechanism past the position in which the links lie along the line AB."[1] AB itself is used as a connection so that the points that it joins, B and A, will be fixed in relation to each other. Now, the following parts remain: BQ, QP, and PA articulated at Q and P, and B and A fixed in their relation to each other (Fig. 28).

It can now be seen that the three movable links have a certain limited movement. Thus, Q can be moved to the left until a point is reached where QPA would be a straight line (Q′P″A), (Fig. 29). Similarly, Q could move to the right to a point where BQP would be a straight line (BQ″P′), (Fig. 30).

If we go one step further, we can add the extensions of BQ and AP so that they will meet at I and also add the handle H to form HBQI. Similarly, we might add PJ to the pin, P, so as to bring our diagram closer to Bennett's Fig. 7. The important thing to remember is that for small movements PQ equals P′Q′ (Fig. 31).

In Bennett's Fig. 7,[1] the mandible piece is QP along with the additions of QC and QS with C and S being placed in positions similar to those of the condyle and symphysis in a two-dimensional representation of the mandible. This entire mandible piece is rigid. P moves perpendicular to PA and hence the center or rotation of the mandible piece is somewhere on API. Similarly, Q is perpendicular to QB and hence the center of rotation of the mandible piece is somewhere on HBQI. Hence the center of rotation is at I. "The point, I, in which the lines of the two links intersect at any time, is *the instantaneous centre of rotation of the mandible piece.*"[1]

An objection that *one might* raise is that in Bennett's mechanism the link-work is operated by means of the handle H, B, and A and therefore they are really not fixed. However, if the segment QPJ is cut off from P to J on a practical model (Fig. 32), and then if BA was fixed rigidly (by means of clamps or by laying the link-work down on a table), then it is obvious that B and A *are* fixed. Again, the handle H is used to turn BQ around B, which is fixed.

In applying this mechanism, we have points representing the condyle and the symphysis. These same points were used in Bennett's Figs. 2, 3, and 4 to which we were able to apply the principles of Bennett's Fig. 1 and arrive at the centrodes by means of which we could then reproduce forms of continuous plane motion. By means of the link-work mechanism (Fig. 33), (mechanically, not biologically) the path of the instantaneous center of rotation becomes apparent.

Bennett's Figure 8.—Although Fig. 8 is open to many questions, I shall limit myself to just two. The line *A* represents an extreme opening component,

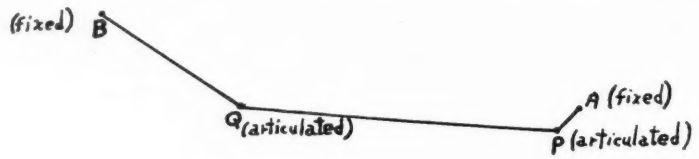


Fig. 28.

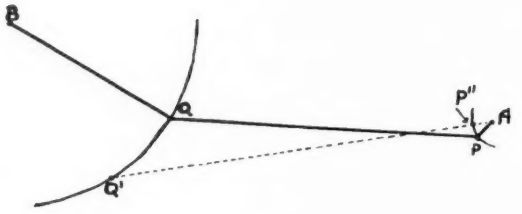


Fig. 29.

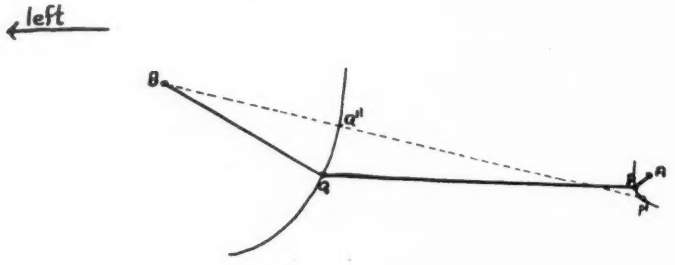


Fig. 30.

right

Fig. 28.—The significant parts of Bennett's Fig. 1. The three segments BQ, QP, PA are articulated at Q and P, and B and A are fixed in their relation to each other.

Fig. 29.—The point Q can be moved to the left until a point is reached where QPA would be a straight line Q'P''A.

Fig. 30.—The point Q can be moved to the right to a point where BQP would be a straight line BQ''P'.

while *B′* represents an extreme opening component combined with an extreme lateral movement to the right. According to this illustration these two lines are perpendicular to one another. How can this come about? If C′ represents an extreme movement to the right with the teeth in continuous occlusion and if B′ represents an extreme opening combined with an extreme movement to the right, then B′ should also be expected to be inclined downward. How could the glow-lamp possibly have registered B′ on the screen as a straight line unless there was definitive pathology present in the temporomandibular joint. Bennett speaks of an extreme opening component combined with an extreme lateral jaw movement *as if there exists just one such combination.* There are a great number of such extreme combinations depending upon which of the two components, the opening or lateral, predominates and the degree of predomination. Bennett does not indicate whether he arrives at his particular combination of the two *extreme* components by first securing the widest jaw separation and then forcing the mandible into an extreme lateral position or whether he starts by moving his mandible to an extreme lateral component. The resultant combinations will differ considerably from one another. When we begin to deal with extreme strained jaw relations we, *ipso facto,* deal with unknown quantities.

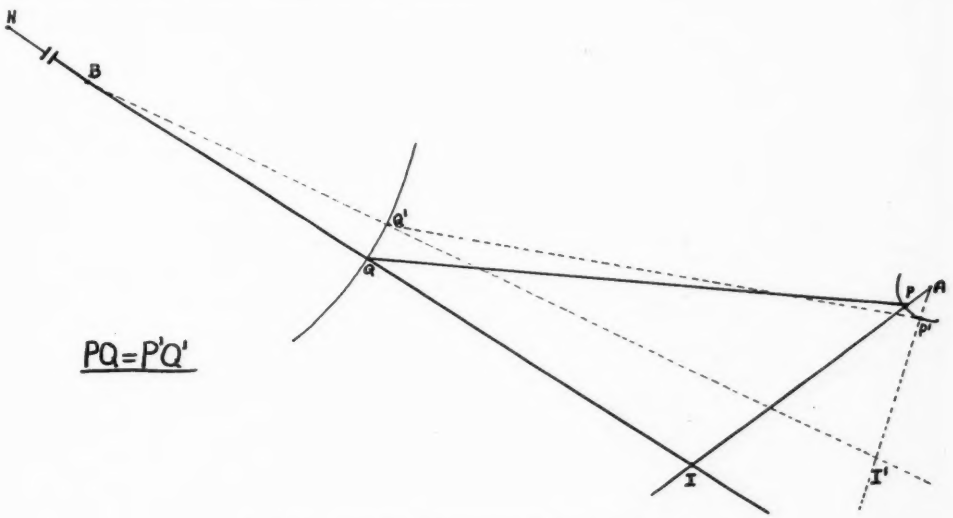


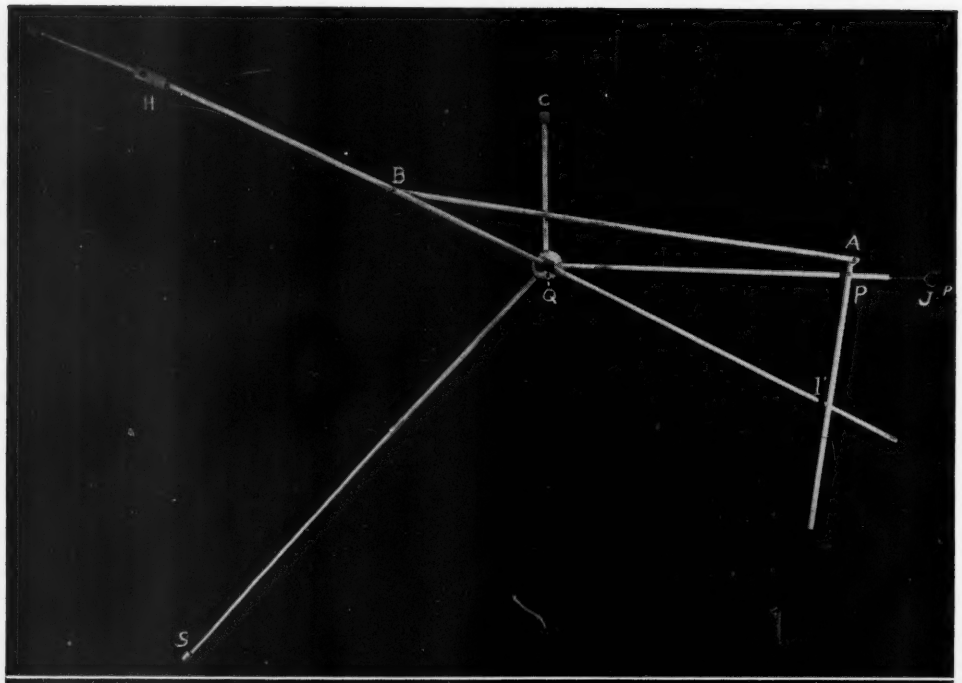
Fig. 31.—For small movements PQ equals P′Q′.

SUMMARY

The Bennett movement was examined in the light of our present knowledge of the anatomy, physiology, and pathology of the temporomandibular joint. It was concluded that Bennett's claim for a "considerable" shift laterally of the mandibular condyle on the working side is lacking in validity. Bennett's optical method of investigation was highly original as a method of approach in the study of mandibular movements, but lacking in scientific precision in several ways:

1. Bennett conducted his investigations on *himself only,* and, according to his own statement, he was missing the molar teeth on both sides of the mandible.

Fig. 32.



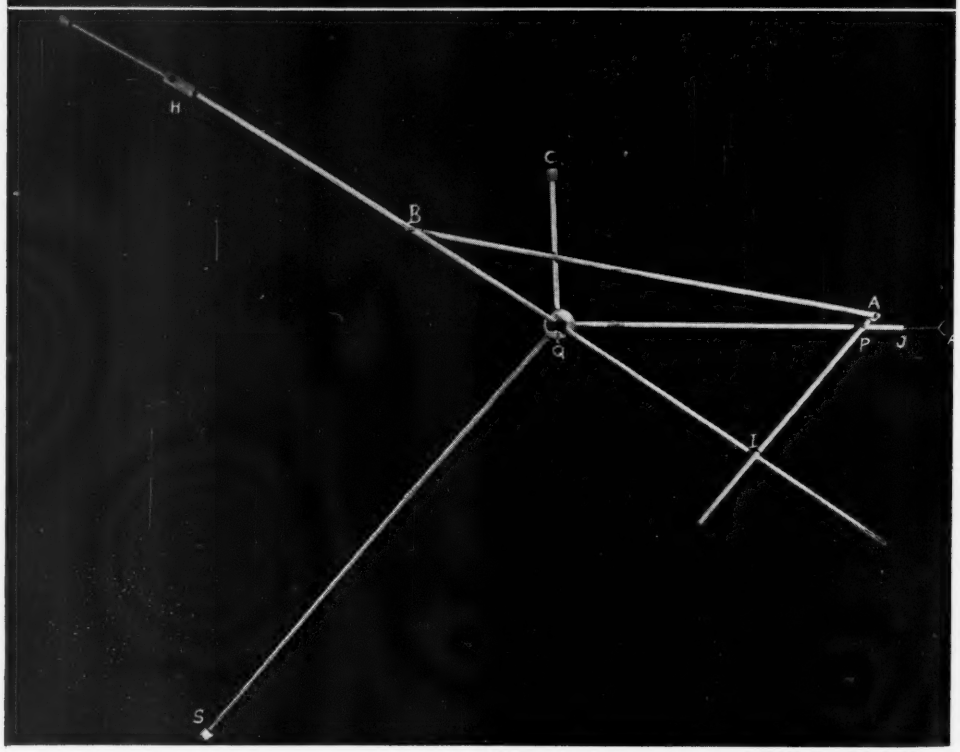


Fig. 33.

Fig. 32.—A working model is constructed of wooden sticks (after the diagrammatic representation of link-work mechanism in Bennett's Fig. 7), and the instantaneous center of rotation is at I'.

Fig. 33.—The same model as in Fig. 12 except that the instantaneous center of rotation happens to be at I instead of I'. By means of the link-work mechanism, we can mechanically reproduce the path of the instantaneous centers of rotation at I', I, and a multiplicity of other instantaneous centers between them.

The pathologic pattern of occlusion that is usually associated with the loss of the molar teeth should have disqualified Bennett as a subject for experimentation.

2. Bennett's experiments were conducted with the mandible in an extreme state of strained relations and strained occlusions.

3. Bennett's slightly larger right side and the resulting asymmetry in his mandibular movements should have disqualified him as a subject of experimentation for the study of the physiology of mandibular movements.

4. In analyzing his own illustration Number 8, Bennett states that his opening component is associated with a slight deviation of his mandible to the right side because of the want of symmetry on his right side.

5. Since Bennett's opening component is associated with a deviation of his mandible to the right, it is reasonable to expect that his right lateral working component would also be associated with a glide of his mandible to the right side—Bennett movement. This does not imply that the Bennett movement is a feature characteristic of people with average normal occlusions.

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RAPID SERIAL ROENTGENOGRAPHIC CEPHALOMETRY FOR OBSERVING MANDIBULAR MOVEMENTS

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THE DENTAL PROFESSION IS constantly in quest of more accurate methods of evaluating mandibular movements because it recognizes the importance of these movements. Many techniques have been used for studying mandibular movements. The methods used by many investigators can be placed into similar groups. Included among the methods are: (1) graphic recordings,[1-10] (2) photographic recordings,[8,11,12] (3) profile roentgenograms,[13,14] (4) roentgenograms of the temporomandibular joints,[15-19] (5) clinical observations,[13-20] (6) the kymographic technique,[21] (7) tomographic methods,[10,22-26] (8) cephalometric roentgenography,[27-33] (9) a combined graphic and roentgenographic technique,[34] and (10) cinefluorography.[35,36]

SERIAL ROENTGENOGRAPHIC CEPHALOMETRY

The use of a rapid cassette changer makes possible the use of serial roentgenographic cephalometry as another technique for the investigation of mandibular movement. This method will allow the investigator to examine the details of mandibular movement in a dynamic rather than static manner within a tolerance of 0.5 mm. The film does not require enlargement since the cassettes can accommodate film as large as 11 by 14 inches. Films of this size or smaller can be exposed at a maximum rate of 6 per second. The possibility of image distortion inherent in photofluoroscopy, with its many systems, is not present in the conventional cephalometric technique, even with the addition of the rapid cassette changer.

When the film changer (Fig. 1) is in operation, the magazine is gradually moved forward by means of a leading screw and is opened automatically. Two levers then enter through the holes and flip the films upward, one at a time. The film is conveyed by two rubber-covered wheels to the exposure position, where it is braked to a full stop and then pressed between two intensifying screens. At the moment when the film is in full compression between the intensifying screens, the automatic exposure interlock is effected. When the compression has ceased, a second pair of rubber-covered wheels feed the film into the film receiver. The film

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receiver cannot be removed until the knob on its side has been pulled out. This action closes the lid and makes the receiver lightproof for transportation to the darkroom, where the film pile is removed (Fig. 2).

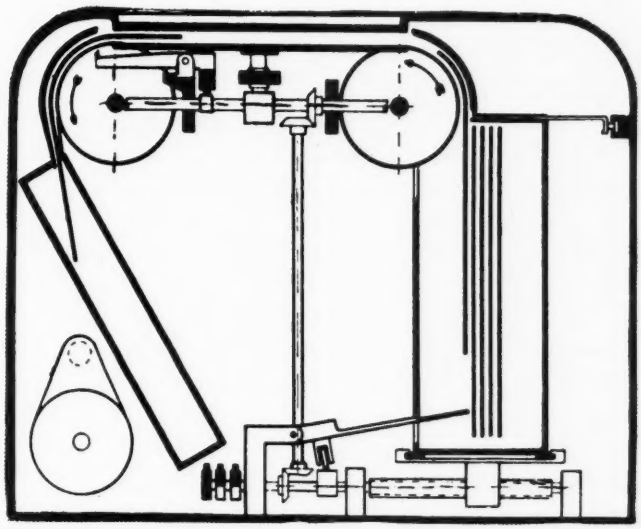

Fig. 1.—A schematic diagram of the Schonander rapid cassette changer. The lever in the lower right portion of the drawing raises the film upward, and the two wheels convey it to the exposure position. After exposure, the film is deposited into the film receiver shown on the left.

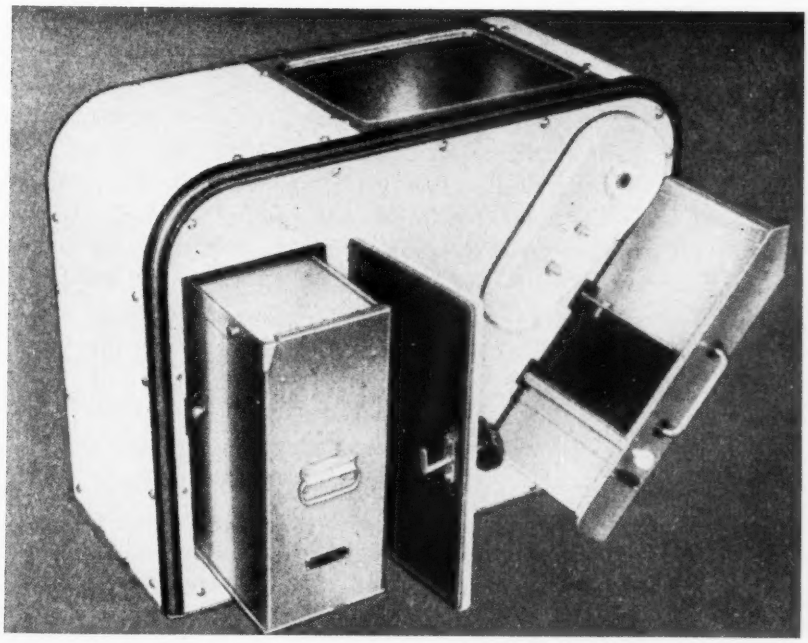

Fig. 2.—External view of a rapid cassette changer, showing the film magazine on the left and the film receiver on the right partially removed.

The film changer can also be used for a single operation, i.e., it can be released manually for single exposures. This makes it possible to obtain test films prior to the serial examination which is an essential requirement. The series can be in-interrupted at any time and, as the changer is x-ray and lightproof, the exposed films can be taken out for developing while leaving the remaining films unexposed.

The exposure field of the apparatus is provided with a fine cross-hatch grid covered by a Bakelite sheet. Exposures are controlled automatically by means of a built-in electronic timer and contact segments, which insure that energy is only applied when a film is ready for exposure. Reloading intervals in the film magazine, therefore, will not expose the patient to unnecessary undesirable radiation.

An important consideration in the use of all rapid cassette changers is the choosing of a suitable roentgen-ray generator. Since this study was restricted to one plane, it necessitated the energization of only one tube. However, the cassette changer may be mounted in either a horizontal or a vertical plane. In addition, two exposures may be made alternately or simultaneously in two planes. If exposures are desired in two planes, duplicate equipment is necessary, and the number of exposures is doubled. Therefore, the radiation factor is doubled. The primary problem of securing the required degree of precision is to obtain intervals as short as possible between the exposures. Suitable exposure data for examining mandibular motion with the cassette changer was 400 Ma. with 85 kv. Virtually any roentgen-ray generator may be used that will supply the power, provided that a timer is incorporated that will permit exposures of 0.016 (1/60) second. There are three major manufacturers of rapid cassette changers.*

SUBJECT RADIATION

Each test subject was exposed to 1.2 r per film with 6 to 8 films being exposed per subject. Dental x-ray units vary in roentgen output from 0.6 to 4.8 r per second or 36 to 288 r per minute. On 40 adult patients, Budowski and others[37] measured, with ionization chambers, the quantity of radiation received by the skin at eight locations on the face while a 14-film roentgenographic examination was made of the patient. They found that the exposure of the skin ranged between 55 and 77 r. Poppel, Sorrentino, and Jacobson[38] recommended that any part of the body exposed to 100 r in air should not be re-exposed for 3 weeks. Doses of between 60 and 100 r in air may be repeated after two weeks of rest, and doses between 30 and 60 r in air may be repeated after one week of rest. Doses below 30 r in air may be repeated daily provided the total dose per week does not exceed 100 r in air. By way of comparison, the subject on which 8 head films had been taken would receive the equivalent radiation (9.6 r) that a patient receives during the exposure of two lower molar periapical films of intermediate speed, 8 inches from the target.

PROCEDURE

A cephalostat was used that had three arms for immobilizing the head. One arm contacted each external auditory meatus, and the remaining arm was placed

*The Sanchez-Perez Company and the Fairchild Company in the United States, and the Elma-Schonander Company in Sweden.

in contact with nasion. The cephalostat could be moved in two planes, anteroposterior and superoinferior. The focal length was 60 inches. The median plane of the cephalostat and the median plane of the subject's head was 10 cm. from the film. The subject's head was placed in the cephalostat with the Frankfort plane oriented approximately in the horizontal plane. The median or sagittal plane was set parallel to the film plane.

In an effort to procure distinct markings on the film, radio opaque lead pellets 1 mm. in diameter were attached to the teeth on the left side of the subject's mouth (Fig. 3). This was the side closest to the cassette, and the enlargement of the pellets was uniform. With the preceding information, the amount of enlargement can be computed arithmetically.

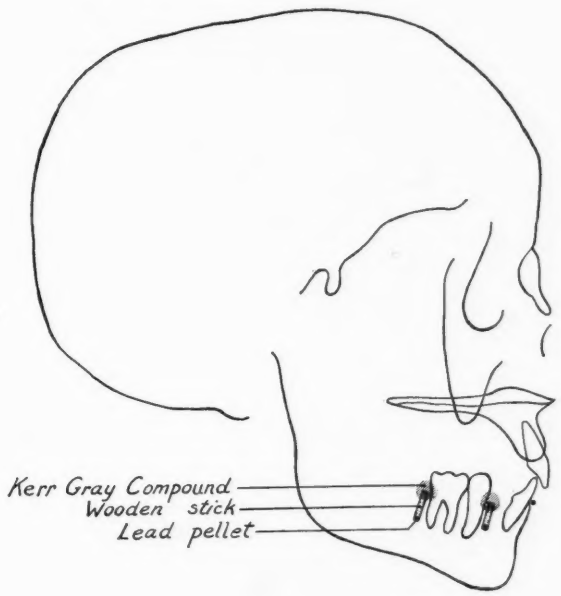

Fig. 3.—Indicator pellets are attached to the buccal surfaces of the teeth with sticky wax or by means of a wooden stick and sticky wax. These pellets serve as reference points in the successive films and on the tracings.

The indicator pellets were attached with sticky wax to the dried buccal surface of the tooth either interproximally or at the gingival margin. In some instances where the subject had had extensive restorative dentistry performed in the past, it was necessary to place the radio opaque pellet on a wooden stick 1.0 cm. in length and have this project down into the buccal sulcus from the interproximal space between the first and second molar (Fig. 3). In addition, a pellet was attached to the labial interproximal space of the lower central incisors, and another pellet was attached to the interproximal space distal to the cuspid. A fourth pellet was attached to the tip of the nose to be used as a check for any movement of the head and to serve as an additional reference point along with the sella turcica, key ridge and nasion, and central incisor. Fig. 4 is an example of a series of cephalometric

roentgenograms showing the test subject executing a closing mandibular movement. Serial cephalometric tracings are made of these and superimposed to form a composite. The movement of the pellets shows a distinct path of closure for the mandible on the composite tracing.

Fig. 4.—A series of roentgenograms made during a mandibular closing movement. Note the indicator pellets which permit comparison of the four successive stages of closure to determine the path of closure. Tracings of each roentgenogram are made and superimposed to demonstrate the path of closure.

SUMMARY

The rapid cassette changer will permit the exposure of six 11 by 14 inch roentgenograms per second. This cassette changer, used with the cephalometric head holder and the technique outlined, makes an accurate method for studying mandibular movement. The accuracy of this procedure is within ± 0.5 mm.

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MATHEMATICAL INTERPRETATION OF MANDIBULAR MOVEMENTS

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THE MOVEMENTS OF THE mandible have been recognized for a long time to be multiple. For the successful construction of complete dentures, these mandibular movements must be registered, reproduced, and intelligently applied to obtain harmony of cusp inclines of the artificial posterior teeth and to obtain a free gliding, efficient, and nontraumatizing occlusion of the dentures in their different excursions.

A number of years ago, Gysi[1] presented his theory of the centers of rotation. The theory states that the center of rotation for mandibular movements is found by tracing perpendicular lines to the paths of movement. The point where the perpendicular lines meet is the center of rotation and the cusp inclines of the posterior teeth must be perpendicular to radii from this center.

This theory was universally accepted and was used as a basis for educational methods, design of articulators, and the design of occlusal surfaces of artificial posterior teeth. I shall introduce a theory that will help to establish a new approach to these problems.

ELLIPTICAL THEORY

An apparatus was built to represent schematically the movements of an articulator in the sagittal plane (Fig. 1). The guides were prolonged until they met to form an angle. Perpendicular lines were traced at right angles to guides *A* and *B* and the supposed center of rotation *(C.R.)* was located at the point of intersection of the perpendicular lines. The guides were set at an angle of 50 degrees and point *P* was marked for later use.

A segment of a circle was traced from the center of rotation *(C.R.)*. According to the theory of the centers of rotation, this curve would represent the path of point *P* if this point were guided by guides *A* and *B* (Fig. 2).

U.M. was added to the apparatus to represent the upper member of the articulator (Fig. 3), and a movable part with a perforation in one end was attached to this member. This perforation was placed on point *P* and a pencil was placed in the perforation. When the upper member was moved along the guides, the true representation of the path traced by point *P* was developed. The difference

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Fig. 1.

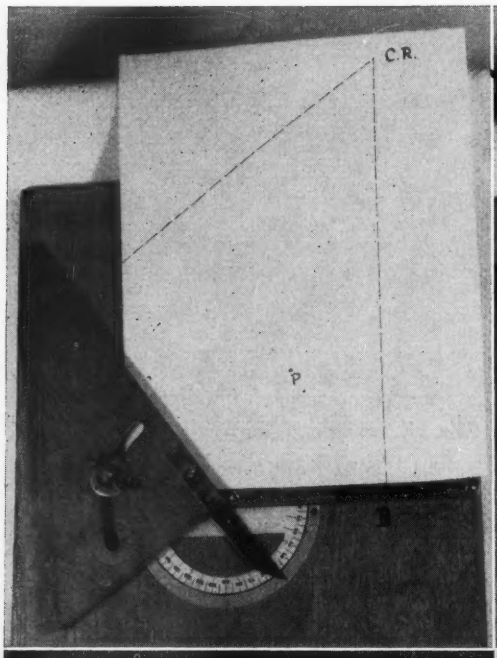
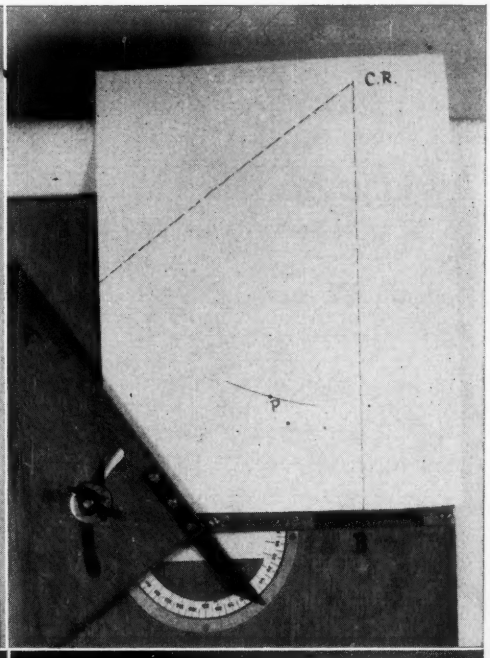


Fig. 2.



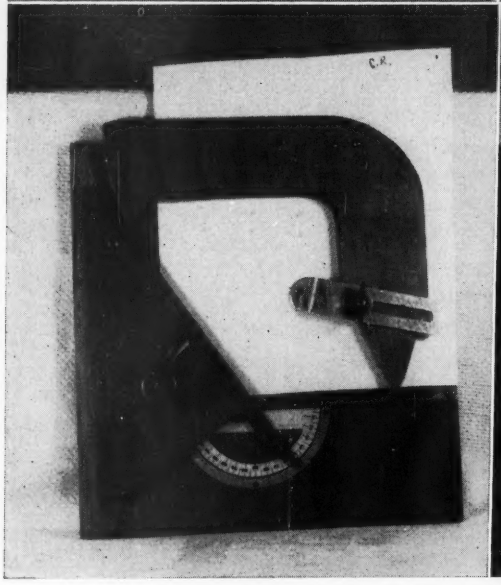


Fig. 3.

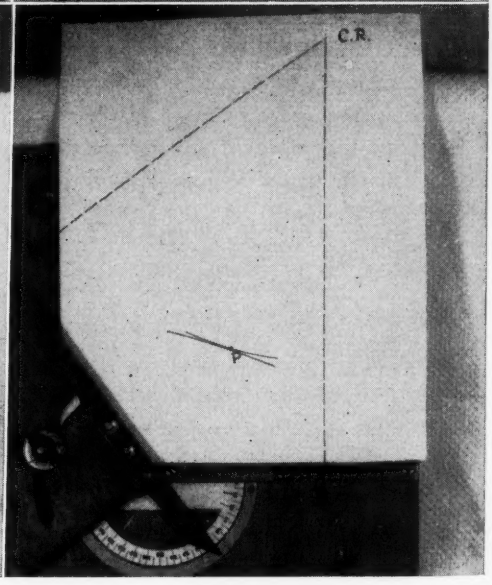


Fig. 4.

Fig. 1.—The apparatus designed to represent an articulator is formed by guides *A* and *B*. *C.R.* is the center of rotation and *P* is the point to be guided to find its correct path in harmony to guides *A* and *B*.

Fig. 2.—The segment of the circle through *P* represents the path of point *P* when guided by *A* and *B* according to the theory of the centers of rotation.

Fig. 3.—The upper member of the articulator is represented by part *U.M.* A movable part with a perforation is located over point *P*.

Fig. 4.—The curve developed by moving *U.M.* along guides *A* and *B* is entirely different from the curve developed when point *P* is used as the center of rotation.

is that the path is longer and its direction and curvature may be judged more easily. This path is entirely different in curvature and direction from the path traced from point *C.R.* (Fig. 4).

To find the kind of curve just developed, the guides were closed to 90 degrees, and point *P* was placed in a movable part that will be moved along the guides (Fig. 5).

Point *P* was moved along the guides until the movable part rested on the horizontal guide (Fig. 6). The resultant curve is not a circular curve; however, the long axis of this curve passes through the point where the two guides meet (Fig. 7).

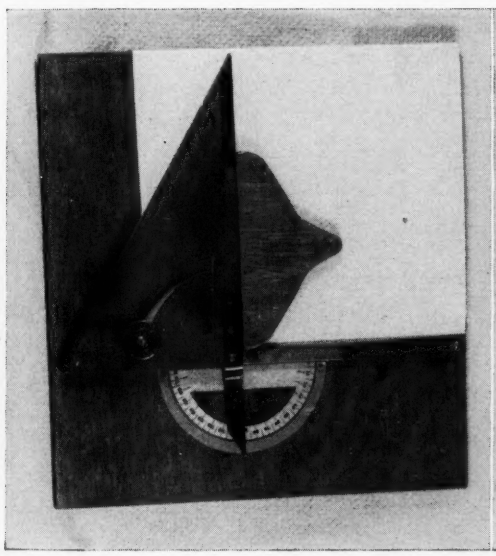


Fig. 5.

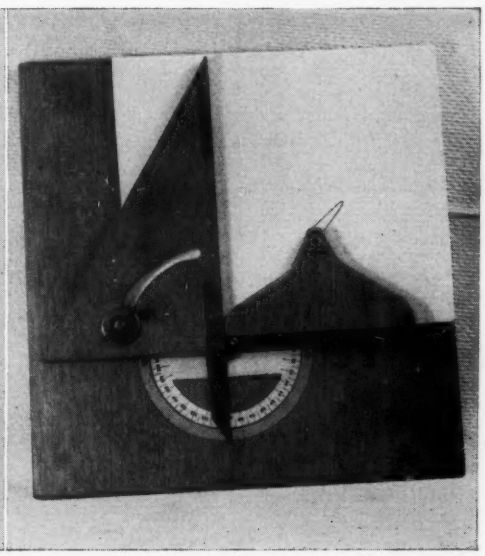


Fig. 6.

Fig. 5.—The guides *A* and *B* have been closed to 90 degrees. Point *P* is placed in a movable part that will be moved along the guides.

Fig. 6.—The movable part has been moved along the guides to trace the path of *P*.

A movable part that has several perforations placed horizontally was placed on the guides, and a pencil was placed in each perforation to trace curves (Fig. 8). The curves developed are all different, but they have one thing in common; the long axis is the same for all the curves, and this long axis passes through the point where the guides meet (Fig. 9).

New curves were traced with the guides set at 70 degrees and the paths are less curved. The center of curvature to each one of these curves is found below and not above the curves (Fig. 10). As the angle of the guides is increased, the paths will have less curvature, but the center of curvature of these paths will still be opposed to the traditional center of rotation.

A similar analysis of the lateral paths on the horizontal plane will give us the same results.

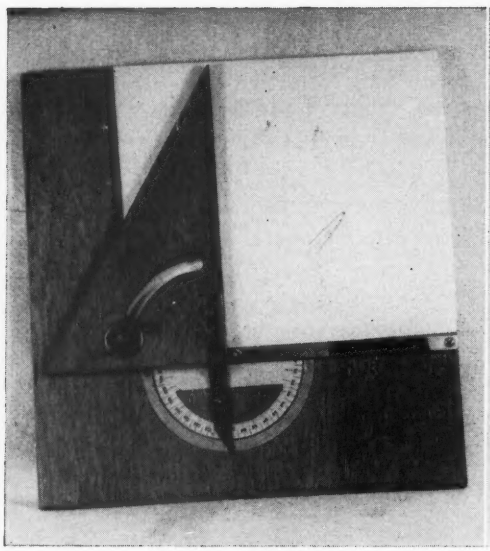


Fig. 7.

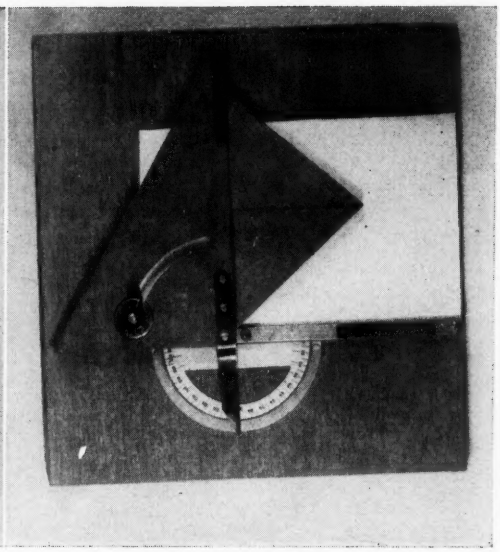


Fig. 8.

Fig. 7.—The long axis of the curve developed passes through the intersection of the guide lines.

Fig. 8.—A movable part with several perforations will be moved along the guide lines.

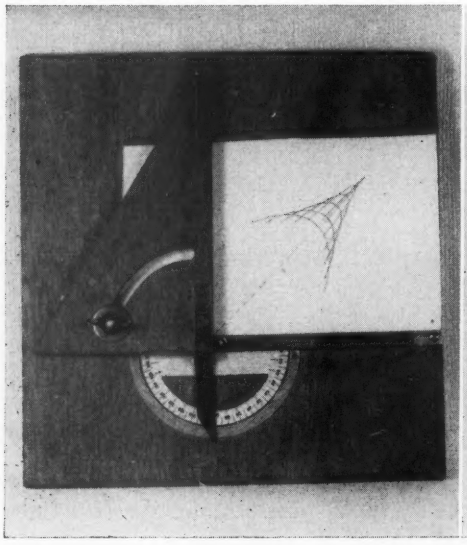


Fig. 9.

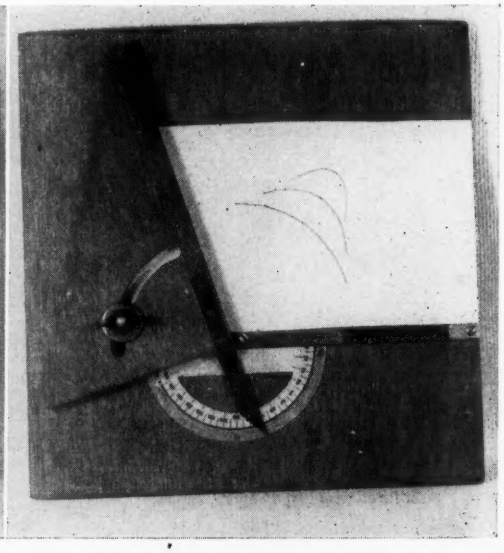


Fig. 10.

Fig. 9.—The curves developed by the movable part in Fig. 8 are all different, but the long axis is the same for all and passes through the intersection of the guide lines.

Fig. 10.—When guide lines *A* and *B* are set at 70 degrees, the paths are less curved. The center of curvature is below and not above the curves.

The paths traveled by the movable member along the guides are translatory movements. However, the movable member also has made a rotational movement because the paths have different direction. *This rotation is not circular,* but it is elliptical. Therefore, we may conclude that the rotational movement of the mandible when guided along two straight guides which are not parallel is an elliptical movement.

This elliptical movement applies not only to the protrusive movement but also to the lateral movements. In the lateral movement, the elliptical rotation becomes an elliptical helix.

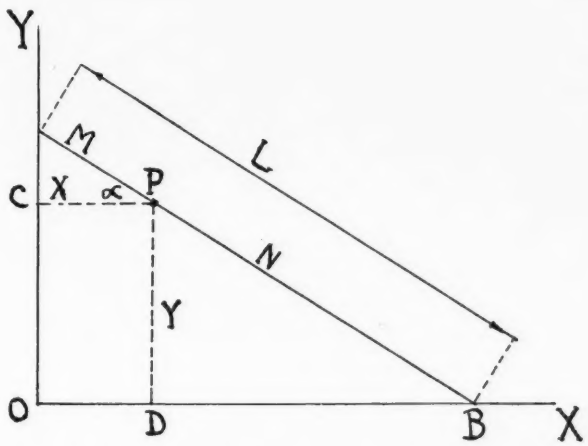


Fig. 11.—The rectangular axes *X* and *Y* represent the paths of movement and line *L* the movable member. Point *P* is the guided point.

MATHEMATICAL PROOF OF ELLIPTICAL THEORY

To further corroborate the veracity of my statements, the analytical geometry is included to demonstrate that we are dealing with an elliptical movement.

When a straight line of fixed length is guided along two fixed axes (abscissa and ordinate) with its ends touching these axes continuously, any point on the line describes an ellipse on the plane—formed by the two coordinate axes. Two rectangular axes *(Y* and *X)* are drawn. Point *P* is placed on line *L* dividing the line in two portions—*M* and *N* so that $M + N = L$ (Fig. 11).

In the triangle P A C we have: $\frac{X}{M} = \text{Cos} \propto$ and in the triangle P D B $\frac{Y}{N} = \sin \propto$

Now $\sin^2 \propto + \cos^2 \propto = 1$. Substituting the values found we obtain:

$$\left(\frac{X}{M}\right)^2 + \left(\frac{Y}{N}\right)^2 = 1$$

$\frac{X^2}{M^2} + \frac{Y^2}{N^2} = 1$ which is the equation of an ellipse with semi-axis equal to M and N.

This same principle holds true when the guiding lines form an angle of more than 90 degrees and are not parallel.

These formulas have no practical application in our work, but they are necessary to identify the curves with which we are dealing and to establish the type of movement made by the articulator. Once we have established these movements, it is easier to relate or determine the necessary requirements of the articulators and to produce an occlusal pattern in artificial posterior teeth that will be in harmony with this movement.

Following the theory of the centers of rotation, the spherical, conical, cylindrical, and paraboloid theories were expressed. These theories are modifications of the primitive theory, and a study in movement has failed to substantiate them.

Nature has pointed the direction in which the centers of curvature of the lateral movements may be found. This direction is seen in persons with natural teeth where the lingual cusps of the upper posterior teeth have disappeared because of wear, producing a transverse curve whose center of curvature is below and not above the occlusal plane. This type of wear is due to the elliptical movement of the mandible.

CONCLUSION

This study has led me to formulate my law of mandibular movements: "The rotational movement of the mandible when guided along two straight guides that are not parallel is an elliptical movement." This law establishes a new approach to the engineering problems of denture construction.

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CLEFT PALATE PROSTHESIS

MEATUS OBTURATOR IN PARTICULAR AND PHARYNGEAL IMPRESSIONS IN GENERAL

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THE "FIXED" AND THE "hinged" obturators are the best known appliances for cleft palate speech correction. For many years, proponents of these two forms have discussed their relative merits. However, Schalit, in 1946, first described in the American literature an entirely different type of obturator, for which he claimed consistently better results.[1] Even though he was essentially correct, Schalit's work went unnoticed, and very few American workers were even aware of its existence. In 1954, a preliminary report on the use of the meatus obturator was published,[2] and since that time, we have used it many times.

The meatus obturator does not depend upon palatal muscle movement for its effectiveness as do the other types of obturators currently in use and, therefore, it does not have their anatomic limitations. It is formed on the presumption that complete occlusion of the oropharynx from the nasopharynx is not necessary for good speech by cleft palate persons. Rather, it is believed that partial occlusion of the nasal cavity will result in a marked diminution or complete elimination of the nasality that is objectionable in the speech of cleft palate patients. If the appliance fulfills this objective, the logopedist need direct his efforts only toward correcting articulative defects rather than to train certain muscles to reduce both hypernasality and the articulative defects as would be necessary with other appliances. This should reduce the number of training sessions necessary to improve the speech for the patient. The results from a properly constructed meatus obturator are remarkable, and the construction is less complicated than the usual "hinge" or "fixed" types of obturators.[3,4] The details of construction were outlined in a previous article.[2]

Whenever it can be used, the meatus obturator is the appliance of choice. However, there is one important limitation. If the two sides of the cleft are very firm and/or the cleft is very narrow, it will not be possible to place sufficient bulk of modeling compound above these palatal remnants. These are the gates

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through which the modeling compound must pass to fill the meatal passage (Fig. 1). If, for example, the modeling compound is 4 cm. wide, and the cleft is only 1.0 cm. wide, not enough warm modeling compound can be inserted to fill the meatus. The relative positions of the obturating mass in the "fixed" and "meatus" appliances are shown in Fig. 2.

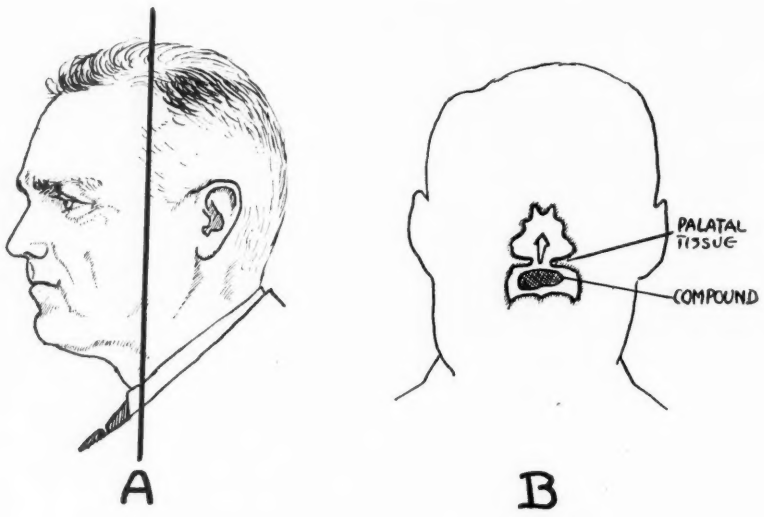

Fig. 1.—Cross section of head showing *(A)* the location of the section, and *(B)* the relationship of the modeling compound mass to the nasal cavity.

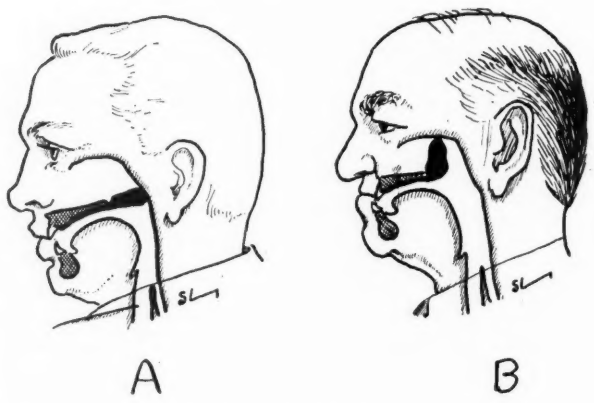

Fig. 2.—The locations of the fixed obturator *(A)* and meatus obturator mass *(B)* in the mouth.

The results of the use of this appliance are so encouraging that we have used it as often as possible and have compromised when it could not be used. In those patients where it is not practical to use a meatus obturator, the level of our "fixed" obturator has been raised as high as feasible, with better results.

Experience in making impressions for constructing a fixed type of appliance (and occasionally the hinge type) has taught us that any attempts to obtain accurate detail in impressions by means of the "wash" materials may be abandoned. This step is superfluous.

There is a certain amount of leakage that will occur around any obturator, and this leakage does not affect the efficiency of the appliance. When the patient swallows, there is a vigorous excursion of the pharyngeal musculature; when he talks, there is less movement of it. Because the appliance must be made comfortable enough for the patient to swallow, an air leak will occur during ordinary speech. Furthermore, the musculature changes its shape, and the detail obtained from a wash impression will not be maintained on tissue topography all of the time.

The procedures used for making impressions for cleft palate prostheses may well be due for evaluation. Several children for whom orthodontic appliances were to be constructed were examined jointly by the orthodontist and the prosthodontist. It was decided that removable appliances which combined orthodontic and prosthodontic treatment should be constructed. However, it was felt that it would be wise to provide the prosthodontic treatment in several progressing steps in order to avoid any antagonism toward the obturating bulb on the part of the child.

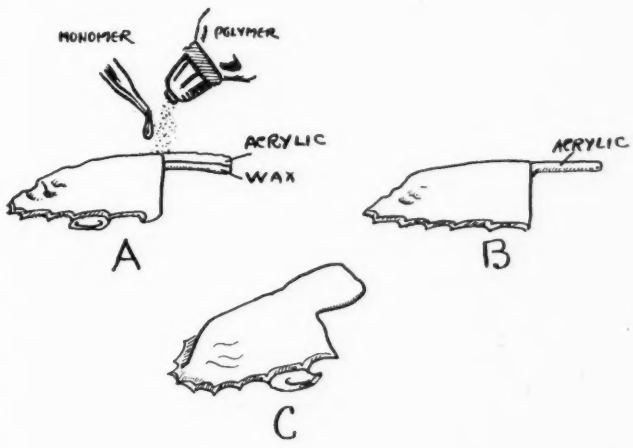

Fig. 3.—A method of fabricating a temporary obturator. *A*, Acrylic resin is sprinkled on a wax platform. *B*, The wax is boiled away. *C*, The finished appliance.

Accordingly, impressions of the pharyngeal area were avoided, and some firm wax was attached to the palatal portion of the acrylic resin appliance which had been finished (Fig. 3). The wax extension was constructed initially to such a dimension that it would not contact the pharyngeal tissues at any time. Acrylic resin was then substituted for the wax, and the patient wore this "bulb" for one week. The next week the "bulb" was enlarged to contact one or two small areas during swallowing. We were planning to accustom the child gradually to a mass

of material in the nasopharynx and then to obtain an impression of the tissues in that region. However, it was noted that when the "bulb" was enlarged (by means of hand molding), there was a marked improvement in the nasal quality of the voice.

Further empirical enlargement of the "bulb" was made at the next appointment. There was some further improvement of the voice, but it was not as dramatic as that of the second appointment. Finally, the pharyngeal impression was made, and the final appliance was placed. The voice quality was not improved over that of the previous week. The results in several succeeding patients treated in this same manner suggest that it may not be necessary to obtain *detailed* impressions for pharyngeal obturators.

It has been interesting to note again and again the secondary role that surgical and prosthetic procedures play in the correction of cleft palate speech. We may work hard and provide our patients with an excellent technical result, but even with our understandable enthusiasm, we are not entirely satisfied with the vocal result. Conversely, we often see patients for whom relatively little has been done, and yet with all their lack of physical equipment, they speak reasonably well. We are convinced that the procedures per se do not make the correction. They merely provide the equipment, and personality heals, either the patient's, the therapist's, or both. However, we need to provide the best equipment possible.

Perhaps the nontraditional thinking behind the meatus obturator is the type of technical approach necessary to cleft palate treatment. The team at this Cleft Palate Center has learned two important facts from working together for several years. First, that "the team approach" is not a platitude but a necessary and rewarding fact, and second, that we have found ourselves talking less and less about the palate and more and more about the person.

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University of Alabama
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Birmingham 3, Ala.

A CASE REPORT ON REPLANTATION

HUGO A. OWENS, D.D.S.
Portsmouth, Va.

OFTEN IN THE PRACTICE of dentistry the very nature of a case will set forth a problem that requires imagination and forthright courage in seeking its solution. This case history is of such a nature.

A 13-year-old boy, while playing on a neighboring school yard, was struck in the mouth and had the maxillary left central incisor knocked completely out. His teacher had the presence of mind to recover the tooth and to rush the patient to the office for emergency treatment.

The patient arrived five minutes after the accident occurred, November 17, 1955. Clinical and roentgenographic examination revealed no fracture of the bone nor damage to any other tooth. The tooth socket was filled with blood, and no foreign bodies were present. The tooth was observed carefully and found to be normal and intact.

The decision to attempt replantation was made. The patient was instructed to bite on a sterile gauze pad while the tooth was being prepared. The tooth was washed thoroughly in a saline solution, rinsed with a solution of Bactine, and scrubbed with gramicidine soap, and then again rinsed with saline solution. The pulp was removed by means of accepted root canal therapy procedures, and the pulp chamber and canal were filled with Kerr's Vitex, after which the length of the tooth at the apex was reduced by approximately 2 mm. The tooth was again cleaned and rinsed in saline solution and replanted in the untreated socket and held firmly in place under moderate pressure for 20 minutes. Four hundred thousand units of penicillin were administered intramuscularly, and an analgesic was prescribed after which the patient was dismissed to return 24 hours later.

The patient reported no undue pain upon his return on Nov. 18, 1955. The tooth was quite immobile but sore to pressure. There was a slight amount of oozing of serum from the socket and considerable edema of the general area. The oral cavity was irrigated with warm saline solution, and the surrounding tissue was swabbed and painted with a counterirritant. The patient was dismissed with instructions to rinse the mouth with warm saline solution every four hours.

Five days later, the patient reported that he felt well in every respect. The soreness of the tooth to pressure had subsided and the edema was less obvious. The oral cavity was irrigated, and counterirritants were applied to the surrounding area.

Received for publication Nov. 18, 1957.

When the patient returned for a fourth postoperative visit on Nov. 28, 1955, roentgenograms were made which revealed no abnormal changes. There were no signs of extrusion, and the tooth was remarkably tight in its socket. The intensity of the soreness to touch had decreased phenomenally.

One month later, the tissue surrounding the replanted tooth had returned to a normal healthy state, the tooth was well anchored, and all soreness had disappeared.

The tooth was not ligated nor splinted to avoid the traumatic injury which might have occurred in occluding with the opposing arch because the patient could not make contact between his upper and lower teeth. Frequent examinations and roentgenograms made over a 2-year period have revealed no pathologic changes in the tooth or its periodontium. The success of the treatment more than justified the decision to elect replantation in preference to a prosthetic appliance which, however finely it may have been constructed, would not have been equal to the patient's own tooth.

600 Green Street
Portsmouth, Va.

READERS' ROUND TABLE

CHICAGO, ILL.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

Schweitzer's article in the September, 1957, issue of your Journal has brought "Transographics" into the field of proper discussion ["The Transograph and Transographic Articulation," J. PROS. DEN. **7**:595-621, 1957]. The main tenet of Transographics, namely, the "split axis," has been exploded by Trapozzano's article ["Discussion of The Transograph and Transographic Articulation by Jerome M. Schweitzer, D.D.S.," J. PROS. DEN. **7**:622-624, 1957]. One may add, however, that it was left to Mr. Page to confuse for the first time the descriptive term "condylar *axis*" with an axis of movement.

The most important point that has to be put into the bright light of scientific scrutiny is not the wealth of incorrect anatomic and physiologic and even of mechanic statements, but the dialectic method used by Mr. Page and quoted by Schweitzer. I will restrict myself to one example only.

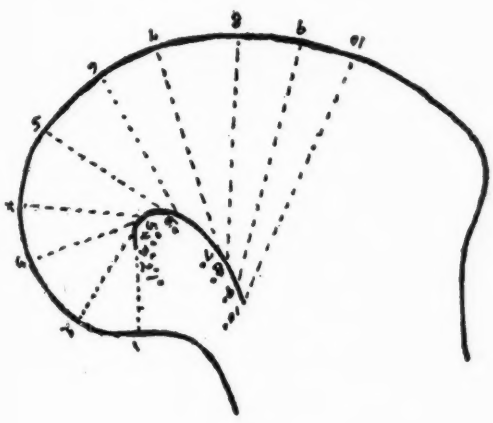

Fig. 1.

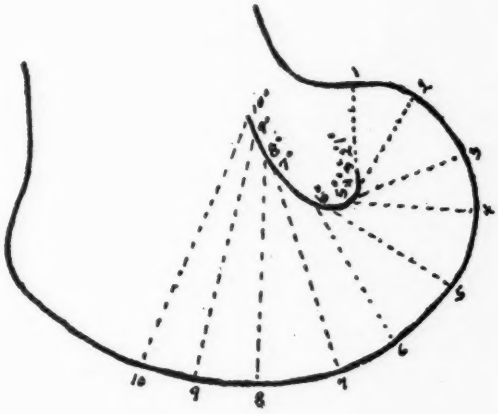

Fig. 2.

On page 601 of the JOURNAL we read: "It is also denied that a hinge axis is scientifically constant to the mandible or to the articular disk even in simple rotation, not to mention a combination of rotary and lateral movements. The irregular condyles make it impossible for the various individual axes to be constant, even in simple rotation. Hjortsjö found that in extensive rotation of the condyle, with no forward movement, the result of the locus of the consecutive axis centers took the form of an evolute curve (Fig. 8)."

This figure (Fig. 8) is a reproduction, in Hjortsjö's paper, of an old figure published by the German anatomist Fick in 1911.

The reader is not left in doubt that Hjortsjö speaks of the mandibular condyle. The reader can also not fail to mistake the reproduction of Fick's figure for a drawing of a mandibular condyle.

What is the truth?

In a paper by Hjortsjö, Persson, and Sonneson, the contour of the *articular eminence* is described as resembling a parabolic curve, and in the *eminence,* therefore, "the locus of the consecutive axis centers took the form of an evolute curve." The authors speak of the upper compartment of the temporomandibular joint and not of the lower one.

The authors then point to another example of such an articulation, namely, the knee joint. Here, Fick showed the evolute curve of loci of movement in the condyle of the femur. It is an astonishing revelation to find that Page, in using the reproduction of Fick's figure in Hjortsjö's paper, has reversed the outline of the femoral condyle so that it now resembles, superficially, a mandibular condyle (Fig. 1). The reader can, without referring to the original paper by Hjortsjö, Persson, and Sonneson, or to Fick's book on Syndesmology, convince himself of this reversal by looking at the numerals 1 to 10 and finding that they are printed upside down (Fig. 2).

I cannot help quoting an old Latin saying: "Sapienti sat."

I want to assure you that this letter is written in the interest of scientific truth, but also in fairness to the readers of your JOURNAL, to the late Dr. Fick, to my good friend Dr. Hjortsjö, and, last but not least, in fairness to Dr. Jerome Schweitzer.

Sincerely yours,

HARRY SICHER, M.D., D.Sc.

BOOK REVIEWS

CLINICAL OPERATIVE DENTISTRY. By William John Simon, B.A., D.D.S., MSD. 381 pages, 650 illustrations, indexed. Philadelphia, 1956, The W. B. Saunders Co. Price $9.50.

This compend, written by the Dean and Professor of Operative Dentistry, State University of Iowa, with an imposing number of contributors, covers exactly what the title implies—the procedures and techniques incidental to the clinical practice of operative dentistry. He states, ". . . the most important criterion for a successful restoration is a cavity preparation which has sound mechanical and biological qualities." Then, by description, explanation, and illustration, he outlines the exacting techniques of cavity preparation for the usual types of restorative materials.

Happily he does not include, as do so many of the traditional texts on operative dentistry, chapters on oral diagnosis, oral pathology, oral anatomy, oral surgery, oral prophylaxis, radiodontics, children's dentistry, endodontics, dental materials, and orthodontics.

He devotes a chapter each to restorations with amalgam, gold inlays, silicate cements, acrylic resin, and gold foil. Included in the discussion of each type is: the preparation of the cavity with variations and modifications; and the methods, techniques, and procedures for constructing the restoration. The illustrations are good and generally adequately explained in the text.

It seems of interest to note the amount of space given to the several restorative materials. There are 137 pages describing gold inlays, 96 for gold foil, 53 for amalgam, 32 for silicate cements, and 31 for acrylic resins. Even if we grant known geographical differences in dental practice, this reviewer—as he has before—poses the question: Are we being realistic in our teaching and fully aware of the current management of dental practice and service when the use of gold foil is emphasized so greatly?

Simon's text should prove to be of use and value both to the student beginning his clinical training and to the practicing dentist who wishes to review operative procedures and improve his clinical technique.

T. F. McBride

EXPECTANT MOTHERHOOD. By Nicholson J. Eastman, M.D. Third Edition, 198 pages, illustrated, indexed. Boston, 1957, Little, Brown & Co. Price $1.75.

This book is a compact and thorough guide for the expectant parent. It explains, step by step, every phase throughout pregnancy, and goes into great detail as to the growth and development of the fetus and the subsequent birth of the child. The final chapters are devoted to the post-partum care of mother and child.

Chapter I discusses the various signs and symptoms of pregnancy, not minimizing the discomforts, but rather explaining their causes and the treatments suggested.

The growth and development of the fetus is exceptionally well written. It is illustrated with pictures and diagrams and is certainly within the scope of understanding of the person not familiar with the usual medical terminology.

The prenatal care of the mother is covered from the standpoint of diet and weight control. Calorie charts and suggested nutrition are included. The mental and physical hygiene of the mother and the visits to the physican are all included.

Chapter VI discusses the danger signals of pregnancy, their indications, possible consequences, and suggested treatment. Rh factor, toxemia, miscarriage, and many other complications of pregnancy are explained.

Preparations for the baby are given in a very practical manner. The birth of the baby, with great detail about the onset of labor, admission to the hospital, and various types of delivery are all widely explored.

The chapter on anesthetics for obstetrics is very informative, explaining the various drugs and their actions.

The final chapters describe the convalescence of the mother and the care of the newborn infant.

Dr. Eastman has presented his book with an amazing amount of information. It is carefully written with emphasis on the many questions that need answering and is undoubtedly the result of careful observation and years of experience.

Nancy J. Reynolds, D.D.S.

FULL DENTURES (The Postgraduate Dental Lecture Series). By Chester Landy, D.M.D., 182 pages, illustrated, indexed. St. Louis, 1958, The C. V. Mosby Co. Price $5.85.

The purpose of this book is to "bridge the gap between the exhaustive textbook and the short scientific article." The book, which is small in size, can be used as a reference and a guide to a modern method of constructing complete dentures.

The manner in which the author presented the subject matter is excellent. It is written in a logical sequence, starting with diagnosis and treatment planning and ending with adjustments and postinsertion treatments. The text material and illustrations are well organized, and the illustrations are of exceptional quality. The reference material is divided into selected references which appear at the end of each chapter and general references which appear at the end of the book. These references cite current literature which covers the field of prosthodontics. The quality of the print can be read easily. The binding is good, and the rounded corners make the book easy to handle.

The impression procedures and jaw relation records are described in an understandable manner. The occlusal scheme is developed on the Hanau Model H articulator, and Hardy inserts and balancing ramps are used as the occluding surfaces.

This book would be excellent for those who follow this concept of making complete dentures. The author could have included more material on deviations from his standard procedures. Many times ideal situations do not prevail, and deviations from a standard procedure or method are necessary to accomplish the desired result.

The book achieves its objective of recording the author's series of postgraduate lectures. It should be of value to the general practitioner of dentistry.

James A. Kreider, D.D.S.

NEWS AND NOTES

MEETINGS

Mid-Continent Dental Congress, Chase-Park Plaza Hotel, St. Louis, Mo., Oct. 12 to 15, 1958. For further information, contact the St. Louis Dental Society, 8013 Maryland Ave., St. Louis 5, Mo.

American Academy of Periodontology, Baker Hotel, Dallas, Texas, Nov. 6 to 8, 1958.

American Denture Society, Adolphus Hotel, Dallas, Texas, Nov. 7 and 8, 1958.

IV Congreso Internacional de Odontologia de Chile, Santiago, Chile, Nov. 16 to 22, 1958.

Greater New York Academy of Prosthodontics, School of Dental and Oral Surgery, Columbia University, New York, N. Y., Dec. 6 and 7, 1958.

Greater New York Dental Meeting, Statler Hotel, New York, N. Y., Dec. 8 to 12, 1958.

Fifteenth Australian Dental Congress, Adelaide, South Australia, Feb. 23 to 27, 1959. For further information, write to the Secretary, Fifteenth Australian Dental Congress, 51 Grenfell St., Adelaide, South Australia.

Southeastern Academy of Prosthodontics, Atlanta Biltmore Hotel, Atlanta, Ga., March 13 to 15, 1959.

American Association for Cleft Palate Rehabilitation, Sheraton Hotel, Philadelphia, Pa., April 30 to May 2, 1959.

ANNOUNCEMENTS

Reprints of the "Glossary of Prosthodontic Terms" may be obtained by writing to Glossary Reprints, 400 Starks Bldg., Louisville, Ky. The price is fifty cents per copy. Please make your check or money order payable to Glossary Reprints and enclose with your order.

The Rowe Smith Memorial Foundation announces the Fifth Annual Seminar at Fly-N-Fish Lodge on Caddo Lake, Karnack, Texas, Jan. 18 to 21, 1959. The subject of this seminar will be "The Blood and Bleeding." For further information, write to the Rowe Smith Memorial Foundation, Inc., 501 State National Bank Bldg., Texarkana, Ark.

Temple University School of Dentistry announces the following graduate and postgraduate courses:

Clinical Endodontics, Oct. 20 to 25, 1958.
The Porcelain Jacket, Nov. 6 to 8, 1958.
Fixed Prosthesis Advanced, Jan. 7, 14, 21, 28, Feb. 4, 11, 25, March 18, 25, 1959.
Clinical Oral Pathology, Jan. 15 to 17, 1959.
Advanced Orthodontics, Jan. 18 to 31, 1959.
Radiodontics-Advanced, Jan. 22 to 24, 1959.
Head and Neck Dissection, Feb. 4 through June 10, 1959.
Periodontal Prosthesis, Feb. 16 to 20, 1959.
Practice Administration, Feb. 28, 1959.
Time, Motion, and Speed, March 1 to 3, 1959.
Oral Medicine for General Practitioner, March 9 to 13, 1959.
Gnathology and Oral Rehabilitation, March 9 to 14, 1959.
Electronic Electrosurgery, March 20 and 21, 1959.

Full Denture Prosthesis, April 6 to 11, 1959.
Full Denture Prosthesis-Advanced, April 12 to 18, 1959.
Advanced Surgical Techniques in Periodontal Therapy, April 18 to 22, 1959.
Transographics in Full Mouth Restoration, May 4 to 9, 1959.
Fundamental Periodontics, June 1 to 5, 1959.
Immediate Root Resection, June 1 to 6, 1959.

For further information and application, write to Postgraduate Division, Temple University School of Dentistry, 3223 North Broad St., Philadelphia 40, Pa.

The University of Alabama, School of Dentistry announces the following refresher courses:
Root Canal Therapy, Oct. 4 to 6, 1958.
Insurance, Investments and Estate Planning, Oct. 18 and 19, 1958.
X-ray Techniques for Dental Hygienists and Assistants, Oct. 24 to 26, 1958.
For further information, write to the Director, Refresher Course Program, University of Alabama, School of Dentistry, 1919 7th Ave. S., Birmingham, Ala.

The University of Washington, School of Dentistry announces a course of graduate study in periodontics. The course is of 18 months' duration.
For further information and application, write to Dr. Saul Schluger, Director, Graduate Dental Education, University of Washington, School of Dentistry, Seattle 5, Wash.

Tufts University School of Dental Medicine announces the following postgraduate refresher courses:
A Special Participation Course in Periodontology, Oct. 6 to 10, 1958.
High Speed Instruments in Operative Dentistry, Oct. 17 and 18, 1958.
Clinical Endodontics, Nov. 7, 14, 21, 28, Dec. 5, 12, 1958.
Operative and Nutritional Procedures for the Management of Rampant Caries, Nov. 10 and 11, 1958.
Oral Roentgenology, Nov. 19, 1958.
Cephalographics and Diagnosis, Jan. 14 to 16, 1959.
Crown and Bridge Prosthesis Participation Course, Jan. 30, 31, Feb. 6, 7, 13, 14, 21, 28, 1959.
Orthodontic Principles of Interest to the General Practitioner, Feb. 4 through March 25, 1959.
Oral Pathology for the Oral Surgeon, Feb. 5 through April 2, 1959.
Full Denture Implants, April 6 to 10, 1959.
Occluso-Rehabilitation I, April 20 to 24, 1959.
Oral Roentgenology, April 22, 1959.
Clinical Dentistry for Children, June 15 and 16, 1959.

For further information and application, write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

The Ohio State University, College of Dentistry announces the following postgraduate courses:

Complete Denture Prosthodontics, Oct. 13 to 17, 1958.
Oral Surgery, Oct. 20 to 24, 1958.
General Anesthesia, Oct. 27 to 31, 1958.
Indirect Technic Bridgework, Nov. 5 and 6, 1958.
Evaluation of Newer Operative Methods, Jan. 23 and 24, 1959.
Crown and Bridge, Jan. 26 to 30, 1959.
Complete Denture Prosthodontics, Feb. 16 to 20, 1959.
Partial Denture Prosthodontics, Feb. 23 to 27, 1959.

Endodontics, March 2 to 6, 1959.
Pedodontics, March 9 to 13, 1959.
General Anesthesia, April 20 to 24, 1959.
Dental Drugs in Action, May 1 and 2, 1959.
Periodontics, May 4 to 8, 1959.

For further information and application, write to Postgraduate Division, College of Dentistry, The Ohio State University, Columbus 10, Ohio.

The New York University, College of Dentistry announces the following postgraduate courses:

Refresher Course in Periodontics and Oral Medicine, Feb. 11 to April 22, 1959. (Wednesdays, 4:00 to 6:00 P.M.)
Periodontics and Oral Medicine in the Spanish Language, March 2 to March 27, 1959.

For further information and application, write to Dr. Sidney Sorrin, Department of Periodontia and Oral Medicine, New York University, College of Dentistry, 209 East Twenty-Third St., New York 10, N. Y.

Western Reserve University, School of Dentistry announces the following postgraduate courses:

Minor Oral Procedures and Emergency Treatment in the Dental Office, Oct., 1958.
Endodontics, Nov. 6 to 8, 1958.
Periodontal Prosthesis, Jan. 3 to 5, 1959.
Psychodynamics and Practice Administration, March 30 through April 1, 1959.

For further information and application, write to Director of Postgraduate Education, School of Dentistry, Western Reserve University, Cleveland 6, Ohio.

University of Pennsylvania, School of Dentistry announces the following postgraduate courses:

Endodontics, Oct. 1, 1958 (Wednesdays, eleven sessions).

Histopathology of the Dental Pulp, Oct. 13 to 17, 1958.

The Use of High Speed Instruments and Equipment, Oct. 15 and 16, 1958.

Complete Denture Prosthesis, Oct. 27 to 31, 1958.

For further information, write to Postgraduate Courses, School of Dentistry, University of Pennsylvania, 4001 Spruce St., Philadelphia 4, Pa.

The Veterans Administration Hospital of Buffalo, N. Y., in conjunction with the University of Buffalo School of Dentistry, announces a two-year residency in prosthodontics.

For further information and application, write to The Chief, Dental Service, V. A. Hospital, 3495 Bailey Ave., Buffalo, N. Y.

Friends of Dr. Clyde Schuyler are tendering a testimonial dinner dance to him on Saturday evening, Oct. 18, 1958 at the Starlight Roof of the Waldorf Astoria Hotel, New York, N. Y.

For further information, write to Dr. Clarence Dunn, Secretary-Treasurer of the Dinner Committee, 875 Fifth Ave., New York, N. Y.

DIRECTORY

OFFICERS OF THE ORGANIZATIONS WHICH HAVE THE JOURNAL OF PROSTHETIC DENTISTRY AS THEIR OFFICIAL PUBLICATION

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Next Meeting: School of Dental and Oral Surgery, Columbia University, New York, N. Y., Dec. 6 and 7, 1958.